Batch RNN

June 28, 2022

```python
[1]: import numpy as np
     import matplotlib.pyplot as plt
     import torch
     from torchvision import datasets
     from torchvision.transforms import ToTensor
     from torch.utils.data import TensorDataset, DataLoader
     import sys
     import copy
```

```python
[2]: def tanh(x):
         return np.tanh(x)

     def d_tanh(x):
         return 1 - np.square(tanh(x))

     def sigmoid(y):
         y[y < -700] = -700
         return 1.0/(1.0+np.exp(-y))

     def d_sigmoid(x):
         z = sigmoid(x)*(1-sigmoid(x))
         return z


     def softmax(x):
         m = nn.Softmax(dim=0)
         return m(torch.tensor(x)).numpy()

     def d_softmax(z):
         '''
         return the jacobian of the softmax
         '''
         z = softmax(z)
         return np.diag(z) - np.outer(z,z)

     def MSE(a,b):
         return np.sum(np.square(a-b), axis = 1)
```

```python
    def d_MSE(output_activations, y):
        return (output_activations - y)
```

```python
[228]: class RNN:

           def __init__(self,input_dim,hidden_dim,output_dim,lr):
               self.input_dim = input_dim
               self.hidden_dim = hidden_dim
               self.output_dim = output_dim
               self.w_in = np.random.uniform(-1,1, (hidden_dim, input_dim))
               self.w_hidden = np.random.uniform(-1,1, (hidden_dim, hidden_dim))
               self.b_hidden = np.random.uniform(-1,1, (hidden_dim, 1))
               self.w_out = np.random.uniform(-1,1, (output_dim, hidden_dim))
               self.b_out = np.random.uniform(-1,1, (output_dim, 1))
               self.loss = []
               self.lr = lr
               self.epsilon = 0.000001

           def forward(self, x):
               hidden_state = np.zeros((self.hidden_dim,1))
               T = x.shape[-1]
               prediction = np.zeros((T,1))

               print(T)
               for i in range(T):
                   x_in = self.w_in @ x[:,i].reshape(self.input_dim,1)
                   x_hid = self.w_hidden @ hidden_state + self.b_hidden
                   hid_out = sigmoid(x_in + x_hid)
                   hidden_state = hid_out
                   x_out = self.w_out @ hid_out + self.b_out
                   prediction[i] = x_out
               return prediction

           def update(self, x, y):

               dldb_hidden,dldb_out,dldw_in,dldw_hidden,dldw_out,loss = self.
       →backprop(x, y)
               self.w_in -=  self.lr * dldw_in
               self.w_hidden -=  self.lr * dldw_hidden
               self.b_hidden -=  self.lr * dldb_hidden
               self.w_out -=  self.lr * dldw_out
               self.b_out -=  self.lr * dldb_out
               self.loss.append(loss)

           def gradient_approximation(self, x, y):
               nable_w_in = np.zeros(self.w_in.shape)
               nable_w_hidden = np.zeros(self.w_hidden.shape)
```

```python
        nable_w_out = np.zeros(self.w_out.shape)
        nable_b_hidden = np.zeros(self.b_hidden.shape)
        nable_b_out = np.zeros(self.b_out.shape)

        aprox1_w_in = np.zeros(self.w_in.shape)
        aprox2_w_in = np.zeros(self.w_in.shape)
        aprox1_w_hidden = np.zeros(self.w_hidden.shape)
        aprox2_w_hidden = np.zeros(self.w_hidden.shape)
        aprox1_w_out = np.zeros(self.w_out.shape)
        aprox2_w_out = np.zeros(self.w_out.shape)
        aprox1_b_hidden = np.zeros(self.b_hidden.shape)
        aprox2_b_hidden = np.zeros(self.b_hidden.shape)
        aprox1_b_out = np.zeros(self.b_out.shape)
        aprox2_b_out = np.zeros(self.b_out.shape)

        for k in range(len(self.b_hidden)):
            aprox1_b_hidden = copy.deepcopy(self.b_hidden)
            aprox2_b_hidden = copy.deepcopy(self.b_hidden)
            aprox1_b_hidden[k] += self.epsilon
            aprox2_b_hidden[k] -= self.epsilon

            hidden_state_1 = np.zeros((batch_size,self.hidden_dim,1))
            loss1 = np.zeros((batch_size,1))
            T = x.shape[-1]
            for i in range(T):
                x_in = self.w_in @ np.expand_dims(x[:,:,i],axis = 2)
                x_hid = self.w_hidden @ hidden_state_1 + aprox1_b_hidden
                hid_out = sigmoid(x_in + x_hid)
                hidden_state_1 = hid_out
                x_out = self.w_out @ hid_out + self.b_out
                loss1 += MSE(x_out,np.expand_dims(y[:,:,i],axis = 2))

            hidden_state_2 = np.zeros((batch_size,self.hidden_dim,1))
            loss2 = np.zeros((batch_size,1))
            T = x.shape[-1]

            for i in range(T):
                x_in = self.w_in @ np.expand_dims(x[:,:,i],axis = 2)
                x_hid = self.w_hidden @ hidden_state_2 + aprox2_b_hidden
                hid_out = sigmoid(x_in + x_hid)
                hidden_state_2 = hid_out
                x_out = self.w_out @ hid_out + self.b_out
                loss2 += MSE(x_out,np.expand_dims(y[:,:,i],axis = 2))

            nable_b_hidden[k] = (np.sum((loss1 - loss2) / (2*self.epsilon))) /␣
↪batch_size
```

```python
    for k in range(len(self.w_in)):
        for j in range(len(self.w_in[k])):
            aprox1_w_in = copy.deepcopy(self.w_in)
            aprox2_w_in = copy.deepcopy(self.w_in)
            aprox1_w_in[k][j] += self.epsilon
            aprox2_w_in[k][j] -= self.epsilon

            hidden_state_1 = np.zeros((batch_size,self.hidden_dim,1))
            loss1 = np.zeros((batch_size,1))
            T = x.shape[-1]
            for i in range(T):
                x_in = aprox1_w_in @ np.expand_dims(x[:,:,i],axis = 2)
                x_hid = self.w_hidden @ hidden_state_1 + self.b_hidden
                hid_out = sigmoid(x_in + x_hid)
                hidden_state_1 = hid_out
                x_out = self.w_out @ hid_out + self.b_out
                loss1 += MSE(x_out,np.expand_dims(y[:,:,i],axis = 2))

            hidden_state_2 = np.zeros((batch_size,self.hidden_dim,1))
            loss2 = np.zeros((batch_size,1))
            T = x.shape[-1]

            for i in range(T):
                x_in = aprox2_w_in @ np.expand_dims(x[:,:,i],axis = 2)
                x_hid = self.w_hidden @ hidden_state_2 + self.b_hidden
                hid_out = sigmoid(x_in + x_hid)
                hidden_state_2 = hid_out
                x_out = self.w_out @ hid_out + + self.b_out
                loss2 += MSE(x_out,np.expand_dims(y[:,:,i],axis = 2))

            nable_w_in[k][j] = (np.sum((loss1 - loss2) / (2*self.epsilon)))␣
↪/ batch_size


    for k in range(len(self.w_hidden)):
        for j in range(len(self.w_hidden[k])):
            aprox1_w_hidden = copy.deepcopy(self.w_hidden)
            aprox2_w_hidden = copy.deepcopy(self.w_hidden)
            aprox1_w_hidden[k][j] += self.epsilon
            aprox2_w_hidden[k][j] -= self.epsilon

            hidden_state_1 = np.zeros((batch_size,self.hidden_dim,1))
            loss1 = np.zeros((batch_size,1))
            T = x.shape[-1]
            for i in range(T):
                x_in = self.w_in @ np.expand_dims(x[:,:,i],axis = 2)
```

```python
            x_hid = aprox1_w_hidden @ hidden_state_1 + self.b_hidden
            hid_out = sigmoid(x_in + x_hid)
            hidden_state_1 = hid_out
            x_out = self.w_out @ hid_out + self.b_out
            loss1 += MSE(x_out,np.expand_dims(y[:,:,i],axis = 2))

        hidden_state_2 = np.zeros((batch_size,self.hidden_dim,1))
        loss2 = np.zeros((batch_size,1))
        T = x.shape[-1]

        for i in range(T):
            x_in = self.w_in @ np.expand_dims(x[:,:,i],axis = 2)
            x_hid = aprox2_w_hidden @ hidden_state_2 + self.b_hidden
            hid_out = sigmoid(x_in + x_hid)
            hidden_state_2 = hid_out
            x_out = self.w_out @ hid_out + + self.b_out
            loss2 += MSE(x_out,np.expand_dims(y[:,:,i],axis = 2))

        nable_w_hidden[k][j] = (np.sum((loss1 - loss2) / (2*self.
    epsilon))) / batch_size

for k in range(len(self.w_out)):
    for j in range(len(self.w_out[k])):
        aprox1_w_out = copy.deepcopy(self.w_out)
        aprox2_w_out = copy.deepcopy(self.w_out)
        aprox1_w_out[k][j] += self.epsilon
        aprox2_w_out[k][j] -= self.epsilon

        hidden_state_1 = np.zeros((batch_size,self.hidden_dim,1))
        loss1 = np.zeros((batch_size,1))
        T = x.shape[-1]
        for i in range(T):
            x_in = self.w_in @ np.expand_dims(x[:,:,i],axis = 2)
            x_hid = self.w_hidden @ hidden_state_1 + self.b_hidden
            hid_out = sigmoid(x_in + x_hid)
            hidden_state_1 = hid_out
            x_out = aprox1_w_out @ hid_out + self.b_out
            loss1 += MSE(x_out,np.expand_dims(y[:,:,i],axis = 2))

        hidden_state_2 = np.zeros((batch_size,self.hidden_dim,1))
        loss2 = np.zeros((batch_size,1))
        T = x.shape[-1]

        for i in range(T):
            x_in = self.w_in @ np.expand_dims(x[:,:,i],axis = 2)
            x_hid = self.w_hidden @ hidden_state_2 + self.b_hidden
            hid_out = sigmoid(x_in + x_hid)
```

```python
                    hidden_state_2 = hid_out
                    x_out = aprox2_w_out @ hid_out + + self.b_out
                    loss2 += MSE(x_out,np.expand_dims(y[:,:,i],axis = 2))

                nable_w_out[k][j] = (np.sum((loss1 - loss2) / (2*self.
↪epsilon))) / batch_size

        for k in range(len(self.b_out)):
            aprox1_b_out = copy.deepcopy(self.b_out)
            aprox2_b_out = copy.deepcopy(self.b_out)
            aprox1_b_out[k] += self.epsilon
            aprox2_b_out[k] -= self.epsilon

            hidden_state_1 = np.zeros((batch_size,self.hidden_dim,1))
            loss1 = np.zeros((batch_size,1))
            T = x.shape[-1]
            for i in range(T):
                x_in = self.w_in @ np.expand_dims(x[:,:,i],axis = 2)
                x_hid = self.w_hidden @ hidden_state_1 + self.b_hidden
                hid_out = sigmoid(x_in + x_hid)
                hidden_state_1 = hid_out
                x_out = self.w_out @ hid_out + aprox1_b_out
                loss1 += MSE(x_out,np.expand_dims(y[:,:,i],axis = 2))


            hidden_state_2 = np.zeros((batch_size,self.hidden_dim,1))
            loss2 = np.zeros((batch_size,1))
            T = x.shape[-1]

            for i in range(T):
                x_in = self.w_in @ np.expand_dims(x[:,:,i],axis = 2)
                x_hid = self.w_hidden @ hidden_state_2 + self.b_hidden
                hid_out = sigmoid(x_in + x_hid)
                hidden_state_2 = hid_out
                x_out = self.w_out @ hid_out + aprox2_b_out
                loss2 += MSE(x_out,np.expand_dims(y[:,:,i],axis = 2))

            nable_b_out[k] = (np.sum((loss1 - loss2) / (2*self.epsilon))) /↪
↪batch_size

        return nable_b_hidden,nable_b_out,nable_w_in,nable_w_hidden,nable_w_out

    def backprop(self, x, y):
        hidden_state = np.zeros((batch_size,self.hidden_dim,1))
        hidden_out = []
        hidden_out.append(hidden_state)
        hidden_z = []
```

```python
        y_out = []
        dldw_in = np.zeros((batch_size,) + self.w_in.shape)
        dldw_hidden = np.zeros((batch_size,) + self.w_hidden.shape)
        dldb_hidden = np.zeros((batch_size,) + self.b_hidden.shape)
        dldw_out = np.zeros((batch_size,) + self.w_out.shape)
        dldb_out = np.zeros((batch_size,) + self.b_out.shape)
        loss = 0
        T = x.shape[-1]

        for i in range(T):
            x_in = self.w_in @ np.expand_dims(x[:,:,i],axis = 2)
            x_hid = self.w_hidden @ hidden_state + self.b_hidden
            hidden_z.append(x_in+x_hid)
            # hid_out = tanh(x_in + x_hid)
            hid_out = sigmoid(x_in + x_hid)
            hidden_out.append(hid_out)
            hidden_state = hid_out
            x_out = self.w_out @ hid_out + self.b_out
            y_out.append(x_out)
            loss += MSE(x_out,np.expand_dims(y[:,:,i],axis = 2))

        '''
        dldw_out
        '''


        for i in range(1,T+1):

            dldb_out += d_MSE(y_out[-i],np.expand_dims(y[:,:,-i],axis = 2))
            dldw_out += d_MSE(y_out[-i],np.expand_dims(y[:,:,-i],axis = 2)) @ 
→np.transpose(hidden_out[-i],(0, 2, 1))

        '''
        dldw_hidden
        dldw_input
        '''

        for i in range(1,T+1):

            delta = d_MSE(y_out[-i],np.expand_dims(y[:,:,-i],axis = 2))
            delta = np.transpose(self.w_out) @ delta * d_sigmoid(hidden_z[-i])
            dldb_hidden += delta
            dldw_hidden += delta @ np.transpose(hidden_out[-i-1],(0, 2, 1))
            dldw_in += delta @ np.transpose(np.expand_dims(x[:,:,-i],axis =
→2),(0, 2, 1))

            for k in range(i+1,T+1):
```

```
                    delta = np.transpose(self.w_hidden) @ delta *␣
↪d_sigmoid(hidden_z[-k])
                    dldb_hidden += delta
                    dldw_hidden += delta @ np.transpose(hidden_out[-k-1],(0, 2, 1))
                    dldw_in += delta @ np.transpose(np.expand_dims(x[:,:,-k],axis =␣
↪2),(0, 2, 1))

        dldb_hidden = 2 * dldb_hidden.sum(axis = 0) / batch_size
        dldb_out = 2 * dldb_out.sum(axis = 0) / batch_size
        dldw_in = 2 * dldw_in.sum(axis = 0) / batch_size
        dldw_hidden = 2 * dldw_hidden.sum(axis = 0) / batch_size
        dldw_out = 2 * dldw_out.sum(axis = 0) / batch_size
        loss = loss.sum(axis = 0) / batch_size

        return (dldb_hidden,dldb_out,dldw_in,dldw_hidden,dldw_out,loss)
```

[451]:
```
input = []
target = []
T = 50
Num = 50


for i in range(Num):

    #parameters = np.random.randint(1,5,(3,1))
    p = np.random.randint(1,5)
    fix = np.array([0,1])
    parameters = np.insert(fix,0,p).reshape(3,1)
    x = np.tile(parameters,(T))
    time = np.linspace(0, 5, T)
    frequency = x[0][0]
    theta = x[1][0]
    amplitude = x[2][0]
    y = amplitude * np.sin(frequency * time + theta)
    input.append(x)
    target.append(y)


batch_size = 5
input = np.array(input)
target = np.array(target).reshape(Num,T)
batch_input = np.split(input, Num/batch_size)
batch_target = np.split(target, Num/batch_size)
```

[452]:
```
%%time
sinrnn = RNN(3,100,1,0.0001)
```

```python
Loss = []

for i in range(500):
    idx = 0
    for input,target in zip(batch_input,batch_target):
        #nable_b_hidden,nable_b_out,nable_w_in,nable_w_hidden,nable_w_out =
    ↪sinrnn.gradient_approximation(input,np.expand_dims(target,axis = 1))
        #dldb_hidden,dldb_out,dldw_in,dldw_hidden,dldw_out,loss = sinrnn.
    ↪backprop(input,np.expand_dims(target,axis = 1))
        #print('approximation',(nable_w_hidden / dldw_hidden).sum())
        sinrnn.update(input,np.expand_dims(target,axis = 1))
        Loss.append(np.sum(sinrnn.loss))
    print('epoch',i,': ',np.sum(sinrnn.loss))
    sinrnn.loss.clear()
```

```
epoch 0 :  334.9824358477371
epoch 1 :  317.020180067336
epoch 2 :  310.7517708382896
epoch 3 :  305.3482641386281
epoch 4 :  300.55079581290954
epoch 5 :  296.21560518859985
epoch 6 :  292.2566088383144
epoch 7 :  288.6173669323599
epoch 8 :  285.2573350802092
epoch 9 :  282.1450676824884
epoch 10 :  279.25479370421317
epoch 11 :  276.5646312984585
epoch 12 :  274.0556042678642
epoch 13 :  271.7110562755419
epoch 14 :  269.51626724885153
epoch 15 :  267.458176860891
epoch 16 :  265.5251684381629
epoch 17 :  263.70689010276925
epoch 18 :  261.9941013642727
epoch 19 :  260.37853895069577
epoch 20 :  258.8527984039949
epoch 21 :  257.41022930964544
epoch 22 :  256.0448426869183
epoch 23 :  254.75122938283153
epoch 24 :  253.52448846230814
epoch 25 :  252.36016465848894
epoch 26 :  251.25419398652951
epoch 27 :  250.2028566553452
epoch 28 :  249.20273644633826
epoch 29 :  248.25068577092142
epoch 30 :  247.34379567042947
epoch 31 :  246.47937008139144
```

```
epoch 32 :    245.65490375363268
epoch 33 :    244.86806327550772
epoch 34 :    244.1166707270789
epoch 35 :    243.39868954604324
epoch 36 :    242.7122122509855
epoch 37 :    242.05544972098593
epoch 38 :    241.4267217791304
epoch 39 :    240.8244488698756
epoch 40 :    240.24714465665602
epoch 41 :    239.69340939696042
epoch 42 :    239.16192397786642
epoch 43 :    238.65144451629834
epoch 44 :    238.16079744566537
epoch 45 :    237.6888750246519
epoch 46 :    237.23463121529306
epoch 47 :    236.79707788658945
epoch 48 :    236.37528130720023
epoch 49 :    235.96835889657802
epoch 50 :    235.5754762085634
epoch 51 :    235.1958441251992
epoch 52 :    234.82871624153677
epoch 53 :    234.47338642466582
epoch 54 :    234.12918653221203
epoch 55 :    233.7954842772243
epoch 56 :    233.47168122777825
epoch 57 :    233.1572109308216
epoch 58 :    232.8515371508167
epoch 59 :    232.55415221463232
epoch 60 :    232.26457545492502
epoch 61 :    231.98235174494792
epoch 62 :    231.70705011834937
epoch 63 :    231.4382624680798
epoch 64 :    231.17560231903235
epoch 65 :    230.91870366949456
epoch 66 :    230.66721989690353
epoch 67 :    230.42082272377107
epoch 68 :    230.17920123998476
epoch 69 :    229.94206097800304
epoch 70 :    229.70912303774335
epoch 71 :    229.48012325822265
epoch 72 :    229.25481143324274
epoch 73 :    229.03295056862996
epoch 74 :    228.8143161787358
epoch 75 :    228.59869562008564
epoch 76 :    228.38588746022955
epoch 77 :    228.1757008800017
epoch 78 :    227.9679551075352
epoch 79 :    227.76247888251174
```

```
epoch 80 :   227.5591099492433
epoch 81 :   227.3576945772968
epoch 82 :   227.1580871084769
epoch 83 :   226.96014952907802
epoch 84 :   226.76375106640668
epoch 85 :   226.56876780866267
epoch 86 :   226.3750823473415
epoch 87 :   226.18258344139886
epoch 88 :   225.99116570248214
epoch 89 :   225.80072930060084
epoch 90 :   225.6111796896632
epoch 91 :   225.422427352361
epoch 92 :   225.2343875639332
epoch 93 :   225.04698017437985
epoch 94 :   224.86012940873596
epoch 95 :   224.67376368504364
epoch 96 :   224.4878154496858
epoch 97 :   224.30222102975847
epoch 98 :   224.1169205021672
epoch 99 :   223.9318575791306
epoch 100 :   223.74697950976199
epoch 101 :   223.56223699737671
epoch 102 :   223.3775841321384
epoch 103 :   223.19297833860878
epoch 104 :   223.0083803377047
epoch 105 :   222.82375412249036
epoch 106 :   222.63906694714197
epoch 107 :   222.45428932831476
epoch 108 :   222.269395058025
epoch 109 :   222.08436122701974
epoch 110 :   221.89916825746036
epoch 111 :   221.71379994358554
epoch 112 :   221.52824349884327
epoch 113 :   221.34248960781068
epoch 114 :   221.1565324810327
epoch 115 :   220.9703699107354
epoch 116 :   220.7840033251962
epoch 117 :   220.59743783939615
epoch 118 :   220.41068229944284
epoch 119 :   220.22374931814338
epoch 120 :   220.03665529903873
epoch 121 :   219.849420446184
epoch 122 :   219.66206875699183
epoch 123 :   219.47462799554177
epoch 124 :   219.28712964392184
epoch 125 :   219.0996088293942
epoch 126 :   218.9121042254848
epoch 127 :   218.7246579254711
```

```
epoch 128 :    218.53731528719396
epoch 129 :    218.350124748628
epoch 130 :    218.16313761421125
epoch 131 :    217.97640781253656
epoch 132 :    217.7899916266324
epoch 133 :    217.60394739868946
epoch 134 :    217.41833521169565
epoch 135 :    217.23321655101327
epoch 136 :    217.04865394943567
epoch 137 :    216.86471061968842
epoch 138 :    216.68145007866102
epoch 139 :    216.49893576787485
epoch 140 :    216.31723067478123
epoch 141 :    216.13639695945676
epoch 142 :    215.9564955911109
epoch 143 :    215.77758599855594
epoch 144 :    215.59972573842583
epoch 145 :    215.42297018447934
epoch 146 :    215.24737224081107
epoch 147 :    215.07298208123723
epoch 148 :    214.8998469165451
epoch 149 :    214.72801079071888
epoch 150 :    214.55751440669707
epoch 151 :    214.38839498169574
epoch 152 :    214.22068613165976
epoch 153 :    214.0544177839939
epoch 154 :    213.88961611737713
epoch 155 :    213.72630352718568
epoch 156 :    213.5644986148384
epoch 157 :    213.40421619922856
epoch 158 :    213.24546734831563
epoch 159 :    213.0882594289133
epoch 160 :    212.93259617270942
epoch 161 :    212.7784777565987
epoch 162 :    212.6259008954698
epoch 163 :    212.47485894568052
epoch 164 :    212.32534201755368
epoch 165 :    212.17733709533545
epoch 166 :    212.03082816317226
epoch 167 :    211.88579633577515
epoch 168 :    211.742219992551
epoch 169 :    211.600074914086
epoch 170 :    211.45933441996908
epoch 171 :    211.31996950703453
epoch 172 :    211.18194898719287
epoch 173 :    211.0452396241008
epoch 174 :    210.909806267992
epoch 175 :    210.77561198806623
```

```
epoch 176 :   210.64261820189245
epoch 177 :   210.51078480134336
epoch 178 :   210.38007027463584
epoch 179 :   210.25043182409735
epoch 180 :   210.1218254793327
epoch 181 :   209.99420620550424
epoch 182 :   209.86752800648514
epoch 183 :   209.7417440226797
epoch 184 :   209.61680662334604
epoch 185 :   209.492667493285
epoch 186 :   209.3692777137966
epoch 187 :   209.24658783783002
epoch 188 :   209.12454795928227
epoch 189 :   209.00310777642645
epoch 190 :   208.88221664947082
epoch 191 :   208.76182365227226
epoch 192 :   208.64187761824576
epoch 193 :   208.52232718052733
epoch 194 :   208.40312080646032
epoch 195 :   208.28420682649121
epoch 196 :   208.16553345756589
epoch 197 :   208.04704882112853
epoch 198 :   207.9287009558302
epoch 199 :   207.81043782505827
epoch 200 :   207.6922073193997
epoch 201 :   207.57395725415324
epoch 202 :   207.45563536200194
epoch 203 :   207.3371892809578
epoch 204 :   207.21856653768336
epoch 205 :   207.09971452629176
epoch 206 :   206.9805804827181
epoch 207 :   206.86111145474896
epoch 208 :   206.74125426778573
epoch 209 :   206.62095548640846
epoch 210 :   206.50016137179594
epoch 211 :   206.37881783504525
epoch 212 :   206.25687038642175
epoch 213 :   206.13426408055707
epoch 214 :   206.01094345759918
epoch 215 :   205.88685248030475
epoch 216 :   205.7619344670485
epoch 217 :   205.63613202071127
epoch 218 :   205.50938695339315
epoch 219 :   205.38164020688365
epoch 220 :   205.25283176880723
epoch 221 :   205.12290058435013
epoch 222 :   204.9917844634591
epoch 223 :   204.85941998339513
```

```
epoch 224 :    204.72574238651168
epoch 225 :    204.59068547312097
epoch 226 :    204.45418148930466
epoch 227 :    204.31616100952184
epoch 228 :    204.1765528138683
epoch 229 :    204.03528375984166
epoch 230 :    203.892278648479
epoch 231 :    203.7474600847426
epoch 232 :    203.6007483320527
epoch 233 :    203.45206116089108
epoch 234 :    203.30131369143493
epoch 235 :    203.1484182302263
epoch 236 :    202.99328410093827
epoch 237 :    202.83581746936997
epoch 238 :    202.6759211628854
epoch 239 :    202.51349448461474
epoch 240 :    202.3484330228576
epoch 241 :    202.18062845626966
epoch 242 :    202.00996835558576
epoch 243 :    201.83633598282645
epoch 244 :    201.65961008916463
epoch 245 :    201.47966471289263
epoch 246 :    201.29636897923373
epoch 247 :    201.1095869040891
epoch 248 :    200.91917720420645
epoch 249 :    200.72499311670902
epoch 250 :    200.52688223142914
epoch 251 :    200.32468634006818
epoch 252 :    200.11824130684764
epoch 253 :    199.90737696604205
epoch 254 :    199.69191705259283
epoch 255 :    199.47167917290662
epoch 256 :    199.24647482394684
epoch 257 :    199.01610946985318
epoch 258 :    198.7803826865674
epoch 259 :    198.5390883863431
epoch 260 :    198.29201513557496
epoch 261 :    198.03894658113614
epoch 262 :    197.77966200240198
epoch 263 :    197.51393700840615
epoch 264 :    197.24154440220428
epoch 265 :    196.96225523760583
epoch 266 :    196.67584009711786
epoch 267 :    196.38207062443215
epoch 268 :    196.08072135035178
epoch 269 :    195.77157185810512
epoch 270 :    195.4544093430883
epoch 271 :    195.1290316340104
```

```
epoch 272 :    194.79525075828838
epoch 273 :    194.45289715587217
epoch 274 :    194.10182467453464
epoch 275 :    193.74191651869526
epoch 276 :    193.37309237633826
epoch 277 :    192.995317018035
epoch 278 :    192.60861075108744
epoch 279 :    192.21306221921904
epoch 280 :    191.80884415261878
epoch 281 :    191.39623275904432
epoch 282 :    190.97563141716367
epoch 283 :    190.54759899791728
epoch 284 :    190.1128821130461
epoch 285 :    189.67244814705958
epoch 286 :    189.22751081375316
epoch 287 :    188.77953023285852
epoch 288 :    188.33015248455345
epoch 289 :    187.8810260657149
epoch 290 :    187.4333898341348
epoch 291 :    186.98725394076564
epoch 292 :    186.53983454966493
epoch 293 :    186.08247931652423
epoch 294 :    185.5943217118594
epoch 295 :    185.03041952803432
epoch 296 :    184.32466564631557
epoch 297 :    183.72465678727
epoch 298 :    183.19452357899561
epoch 299 :    186.26362179234772
epoch 300 :    204.93566955920534
epoch 301 :    187.7807159198105
epoch 302 :    183.80025141822497
epoch 303 :    187.10501661963121
epoch 304 :    214.50287257512932
epoch 305 :    192.88918256917844
epoch 306 :    191.73551672016276
epoch 307 :    203.3800617441542
epoch 308 :    188.43964258343922
epoch 309 :    181.65982007222604
epoch 310 :    181.03950550770753
epoch 311 :    181.30561583972897
epoch 312 :    209.52255804161578
epoch 313 :    196.03812768122518
epoch 314 :    211.36861059732468
epoch 315 :    201.38619849219566
epoch 316 :    183.91377132009194
epoch 317 :    183.52645638034062
epoch 318 :    213.07547815848469
epoch 319 :    204.67743594567688
```

```
epoch 320 :    186.08172618258232
epoch 321 :    181.4149077167611
epoch 322 :    210.1723857850783
epoch 323 :    203.93124282413692
epoch 324 :    185.25042968121417
epoch 325 :    182.75889294031572
epoch 326 :    209.80529513018325
epoch 327 :    204.310133962529
epoch 328 :    186.47870369659242
epoch 329 :    185.61815668791334
epoch 330 :    199.2082017251169
epoch 331 :    187.89537359667577
epoch 332 :    202.6371735346224
epoch 333 :    198.65519403969134
epoch 334 :    183.28125478816855
epoch 335 :    208.52080814772074
epoch 336 :    205.77950296164803
epoch 337 :    191.24285182247468
epoch 338 :    194.0238172322396
epoch 339 :    184.9760248457267
epoch 340 :    192.10690726087685
epoch 341 :    183.34397977050907
epoch 342 :    196.0978943735655
epoch 343 :    189.93700912679242
epoch 344 :    208.8426429081394
epoch 345 :    207.53439063050027
epoch 346 :    196.2088569004113
epoch 347 :    180.88160108539486
epoch 348 :    197.24356379037962
epoch 349 :    193.81844362850492
epoch 350 :    193.64805418960128
epoch 351 :    183.8774144413211
epoch 352 :    199.17900028032722
epoch 353 :    198.59197961207988
epoch 354 :    180.15942658498648
epoch 355 :    209.16701451144507
epoch 356 :    209.43179637661424
epoch 357 :    201.7888191656783
epoch 358 :    189.5369523435468
epoch 359 :    189.99368703401692
epoch 360 :    181.39889457829045
epoch 361 :    203.80915625551867
epoch 362 :    205.5189224881055
epoch 363 :    194.74877263024803
epoch 364 :    179.67559560911073
epoch 365 :    204.69395064116864
epoch 366 :    205.98233660224648
epoch 367 :    197.43948493185246
```
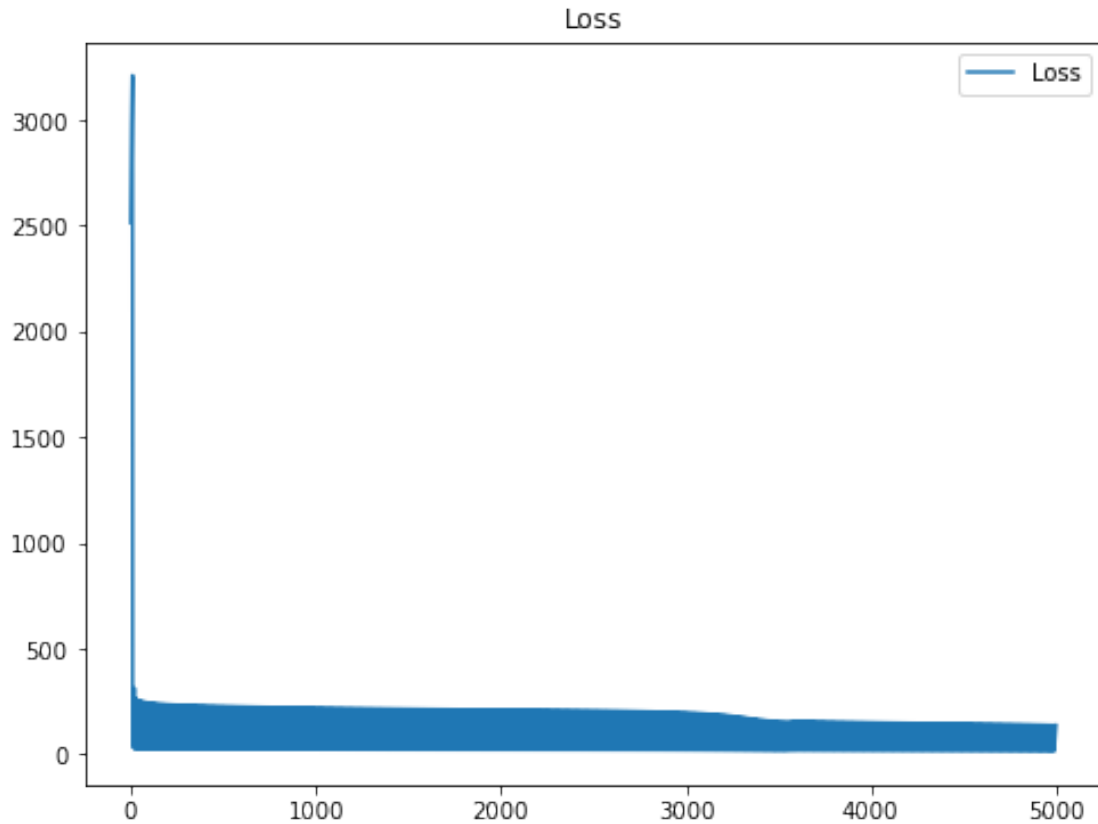
```
epoch 368 :   182.26369321671731
epoch 369 :   197.27201664972915
epoch 370 :   197.26572353103992
epoch 371 :   180.04024547961328
epoch 372 :   204.47867722357705
epoch 373 :   206.40336695181495
epoch 374 :   198.77364279549457
epoch 375 :   184.97757670016378
epoch 376 :   193.79814351761686
epoch 377 :   191.1277476638013
epoch 378 :   188.30556837758292
epoch 379 :   179.13029066103914
epoch 380 :   209.7589993167643
epoch 381 :   209.8705563764127
epoch 382 :   204.75805447086927
epoch 383 :   199.30307906895078
epoch 384 :   189.0310727830386
epoch 385 :   183.3692521459079
epoch 386 :   187.00476925131608
epoch 387 :   178.4787163234786
epoch 388 :   206.84243520834454
epoch 389 :   208.18922019496782
epoch 390 :   202.79457255637266
epoch 391 :   195.93711688451057
epoch 392 :   182.17437923128284
epoch 393 :   191.97051217196292
epoch 394 :   189.49786045084568
epoch 395 :   184.57625796895798
epoch 396 :   182.32944755017752
epoch 397 :   191.384145039095
epoch 398 :   183.96367935646458
epoch 399 :   195.34526598415817
epoch 400 :   194.79619562353074
epoch 401 :   176.88063475048926
epoch 402 :   199.5656141867294
epoch 403 :   202.09785859116636
epoch 404 :   190.48131359006442
epoch 405 :   186.67410619721812
epoch 406 :   178.0982994767784
epoch 407 :   207.92785144739443
epoch 408 :   209.12146344642963
epoch 409 :   204.9098638619161
epoch 410 :   200.88729784376832
epoch 411 :   194.69499730962
epoch 412 :   181.2640343553665
epoch 413 :   188.9008385871112
epoch 414 :   184.86938455288313
epoch 415 :   185.09376266902188
```

```
epoch 416 :   176.61209003695419
epoch 417 :   189.0307729907131
epoch 418 :   181.3895641371193
epoch 419 :   208.84999560092663
epoch 420 :   209.49468286430053
epoch 421 :   205.5043703548154
epoch 422 :   202.0748473063216
epoch 423 :   197.61893027901812
epoch 424 :   188.45677597416042
epoch 425 :   178.24897524743932
epoch 426 :   182.26836211234556
epoch 427 :   178.83983703561205
epoch 428 :   177.1893560362584
epoch 429 :   208.7959208387086
epoch 430 :   209.1853033205015
epoch 431 :   205.34169510742433
epoch 432 :   202.1198889030818
epoch 433 :   198.12327863836444
epoch 434 :   190.48652336348428
epoch 435 :   176.15523446991816
epoch 436 :   189.94091523705393
epoch 437 :   189.12165436684558
epoch 438 :   184.67180556711247
epoch 439 :   176.62213180667385
epoch 440 :   201.7559105839199
epoch 441 :   205.0804883505132
epoch 442 :   200.1736188186705
epoch 443 :   193.36968987269105
epoch 444 :   178.83255391758294
epoch 445 :   189.1371304703126
epoch 446 :   188.07855100661936
epoch 447 :   184.32626410390037
epoch 448 :   176.11970358138595
epoch 449 :   201.39252867157902
epoch 450 :   204.84908765636217
epoch 451 :   200.0609938288734
epoch 452 :   193.54846843480274
epoch 453 :   179.4233093096805
epoch 454 :   187.7911341029542
epoch 455 :   185.94649074339938
epoch 456 :   178.00465917143123
epoch 457 :   175.33971174503765
epoch 458 :   175.0695267365221
epoch 459 :   174.87723816305333
epoch 460 :   208.31171296832008
epoch 461 :   208.59003287996546
epoch 462 :   204.7022071573293
epoch 463 :   201.49312889369781
```

```
epoch 464 :   197.58821002274115
epoch 465 :   190.3585190324648
epoch 466 :   175.29499662227886
epoch 467 :   186.61170359632155
epoch 468 :   183.73257260247158
epoch 469 :   176.97386895599865
epoch 470 :   174.1315876941742
epoch 471 :   200.88969965828437
epoch 472 :   204.63183212777682
epoch 473 :   200.00338677356157
epoch 474 :   194.02698346027637
epoch 475 :   180.8795200094848
epoch 476 :   183.3822861621257
epoch 477 :   177.17971338248287
epoch 478 :   195.69813463008344
epoch 479 :   200.1776556596303
epoch 480 :   192.7276804815012
epoch 481 :   177.19294656367921
epoch 482 :   189.44676082437198
epoch 483 :   191.66657706795098
epoch 484 :   173.97920282051714
epoch 485 :   194.768553319724
epoch 486 :   199.2636310474023
epoch 487 :   190.99125758932803
epoch 488 :   174.31967804491347
epoch 489 :   189.24461902861069
epoch 490 :   191.22737853488223
epoch 491 :   173.2434721897706
epoch 492 :   195.32566849323632
epoch 493 :   199.95052721858528
epoch 494 :   192.72702321310553
epoch 495 :   177.72826336107744
epoch 496 :   186.2203261103288
epoch 497 :   185.57193153774045
epoch 498 :   181.06365078598904
epoch 499 :   172.89573858264708
CPU times: user 12min 16s, sys: 1.37 s, total: 12min 17s
Wall time: 12min 17s
```

[417]:
```python
plt.figure(figsize = (8, 6))
plt.plot(Loss, label = 'Loss', markersize = 3)
plt.title("Loss")
plt.legend()
plt.show()
```

Loss

```
[453]: for i in range(500,1000):
           for input,target in zip(batch_input,batch_target):
               sinrnn.update(input,np.expand_dims(target,axis = 1))
               Loss.append(np.sum(sinrnn.loss))
           print('epoch',i,': ',np.sum(sinrnn.loss))
           sinrnn.loss.clear()
```

```
epoch 500 :  198.24944756470492
epoch 501 :  202.5444883848307
epoch 502 :  197.45436722823044
epoch 503 :  189.84922773637317
epoch 504 :  173.92292426693962
epoch 505 :  184.4960952117848
epoch 506 :  181.6608038112666
epoch 507 :  176.2926666643467
epoch 508 :  184.8534715946752
epoch 509 :  180.4805952762221
epoch 510 :  176.84409165695405
epoch 511 :  181.71584382087377
epoch 512 :  174.01212389699123
epoch 513 :  201.08760487224978
```

```
epoch 514 :  204.56618449056907
epoch 515 :  200.37877496468496
epoch 516 :  195.83047839800435
epoch 517 :  187.82127452574198
epoch 518 :  171.76495285539806
epoch 519 :  183.8068260791311
epoch 520 :  181.46353852913788
epoch 521 :  175.03745045641867
epoch 522 :  182.16293727215896
epoch 523 :  174.94470148982015
epoch 524 :  195.8491044659138
epoch 525 :  200.61273931693222
epoch 526 :  194.4432023958976
epoch 527 :  183.2766026936142
epoch 528 :  174.14490100345577
epoch 529 :  178.95078577325538
epoch 530 :  170.72901570681202
epoch 531 :  195.2472104052692
epoch 532 :  199.99600510064937
epoch 533 :  193.43276515517982
epoch 534 :  181.0683364357388
epoch 535 :  175.29763014850812
epoch 536 :  169.33497172294577
epoch 537 :  175.47832506660305
epoch 538 :  176.24702380532764
epoch 539 :  168.29740843139552
epoch 540 :  174.10512762802097
epoch 541 :  171.27223277379645
epoch 542 :  169.52829327404083
epoch 543 :  183.90735008346488
epoch 544 :  178.60397953638386
epoch 545 :  176.72492288247003
epoch 546 :  167.70911395335517
epoch 547 :  176.43872217796675
epoch 548 :  169.04740058495315
epoch 549 :  169.0886068866996
epoch 550 :  168.70257653326462
epoch 551 :  174.43481708539767
epoch 552 :  180.14106418269301
epoch 553 :  176.38138332177317
epoch 554 :  197.75603433370344
epoch 555 :  202.45918032594003
epoch 556 :  196.23859431011766
epoch 557 :  186.5965134981833
epoch 558 :  167.9752625322221
epoch 559 :  183.32585478050504
epoch 560 :  184.19404644186034
epoch 561 :  175.8827440123618
```

```
epoch 562 :    167.40344985822344
epoch 563 :    193.20202696999078
epoch 564 :    198.07641062082675
epoch 565 :    188.81564245734327
epoch 566 :    170.4653649300191
epoch 567 :    185.54429933266772
epoch 568 :    188.14160175300586
epoch 569 :    168.38014366917847
epoch 570 :    188.2316379856375
epoch 571 :    192.98477059621817
epoch 572 :    177.77224149029576
epoch 573 :    176.18715447964436
epoch 574 :    167.83445259399238
epoch 575 :    189.9982050996111
epoch 576 :    195.41831014289696
epoch 577 :    183.9798219040802
epoch 578 :    165.71554285368546
epoch 579 :    185.57036032225938
epoch 580 :    188.92634926376797
epoch 581 :    169.91016033617257
epoch 582 :    184.4591722771166
epoch 583 :    186.9021545737937
epoch 584 :    167.1127045128086
epoch 585 :    185.36817306802558
epoch 586 :    188.79760423147707
epoch 587 :    169.7864413102939
epoch 588 :    182.92408557095206
epoch 589 :    184.24752996773327
epoch 590 :    164.847795846819
epoch 591 :    187.38818854700287
epoch 592 :    191.62295779832039
epoch 593 :    175.92598722036107
epoch 594 :    174.91083610676614
epoch 595 :    166.81460693811192
epoch 596 :    186.49677459156402
epoch 597 :    190.63898115006486
epoch 598 :    173.72105549381132
epoch 599 :    177.15318609572267
epoch 600 :    171.23371679665968
epoch 601 :    183.14393095410298
epoch 602 :    184.79804138755856
epoch 603 :    164.84538531461126
epoch 604 :    182.91567269905036
epoch 605 :    184.87736770024674
epoch 606 :    164.72813132654682
epoch 607 :    182.77560397188935
epoch 608 :    184.7066998003348
epoch 609 :    164.48831090434518
```

```
epoch 610 :   182.42572425574437
epoch 611 :   184.1404888840592
epoch 612 :   163.93608524051956
epoch 613 :   182.71990758694696
epoch 614 :   184.71320256747794
epoch 615 :   164.32903466215944
epoch 616 :   180.94280317545605
epoch 617 :   181.49150970183283
epoch 618 :   162.8212539402514
epoch 619 :   181.15531960544803
epoch 620 :   180.15076706310697
epoch 621 :   166.80941821164575
epoch 622 :   170.80729735695883
epoch 623 :   162.32855723246823
epoch 624 :   180.07962071511085
epoch 625 :   176.52124535576183
epoch 626 :   168.37624734925475
epoch 627 :   175.69587002713445
epoch 628 :   167.3153235858682
epoch 629 :   181.05645734820217
epoch 630 :   182.3390571874286
epoch 631 :   161.4569987870986
epoch 632 :   183.63560400986017
epoch 633 :   186.52210372690502
epoch 634 :   166.2628558899888
epoch 635 :   174.48058017552086
epoch 636 :   168.85519842115355
epoch 637 :   181.35341209196983
epoch 638 :   182.4415780781769
epoch 639 :   161.5591508520815
epoch 640 :   177.41427808645753
epoch 641 :   175.20456035602757
epoch 642 :   168.5745539450775
epoch 643 :   160.61479983719377
epoch 644 :   180.86154587654949
epoch 645 :   179.9082031147004
epoch 646 :   160.1098816820844
epoch 647 :   182.11140650635772
epoch 648 :   183.21233121625386
epoch 649 :   161.87127221942768
epoch 650 :   175.52241446388607
epoch 651 :   171.67856624532217
epoch 652 :   174.00805607586574
epoch 653 :   166.7632181822241
epoch 654 :   177.4543594457402
epoch 655 :   175.73890521022702
epoch 656 :   168.42411858660788
epoch 657 :   159.1917738743095
```

```
epoch 658 :    183.1166219598456
epoch 659 :    185.74628450797536
epoch 660 :    165.83207833534428
epoch 661 :    169.34913299292094
epoch 662 :    161.30635133674338
epoch 663 :    176.94662733739096
epoch 664 :    175.51766202537755
epoch 665 :    166.8288440664002
epoch 666 :    157.76944491066834
epoch 667 :    183.63022946685302
epoch 668 :    186.261988599711
epoch 669 :    167.46692970753884
epoch 670 :    168.322467821885
epoch 671 :    159.75083122810062
epoch 672 :    174.13703376740864
epoch 673 :    170.33376497838935
epoch 674 :    169.34919100905012
epoch 675 :    159.69884682895312
epoch 676 :    174.2503194218022
epoch 677 :    170.80837213175275
epoch 678 :    167.12490011852498
epoch 679 :    157.02207323720378
epoch 680 :    177.2976384302179
epoch 681 :    176.84121166242568
epoch 682 :    155.2717228657098
epoch 683 :    174.61563350175584
epoch 684 :    171.8190789807155
epoch 685 :    165.72719952965548
epoch 686 :    155.5963102106594
epoch 687 :    175.58565089275749
epoch 688 :    173.96801089050112
epoch 689 :    155.35534178155416
epoch 690 :    175.63808683101982
epoch 691 :    172.42672692460422
epoch 692 :    156.54768587633774
epoch 693 :    165.89139983594498
epoch 694 :    154.84353142553175
epoch 695 :    170.427185609472
epoch 696 :    164.6925400185089
epoch 697 :    174.58431335632068
epoch 698 :    171.07546403698373
epoch 699 :    153.7133514685843
epoch 700 :    171.7418094762678
epoch 701 :    165.39627594354494
epoch 702 :    165.43857495776672
epoch 703 :    154.96342952608742
epoch 704 :    159.8230701020177
epoch 705 :    150.6000382221719
```

```
epoch 706 :   181.93742507137426
epoch 707 :   182.41730663437897
epoch 708 :   163.96935625200985
epoch 709 :   156.59686810777893
epoch 710 :   147.88151647425747
epoch 711 :   175.5872597666983
epoch 712 :   173.54111575187468
epoch 713 :   150.5397001008146
epoch 714 :   151.28278592060533
epoch 715 :   158.39745056289368
epoch 716 :   145.97909203803522
epoch 717 :   162.39422001049533
epoch 718 :   152.60706251310907
epoch 719 :   171.8079386571859
epoch 720 :   167.62090827791837
epoch 721 :   142.72373762270277
epoch 722 :   146.34042546741858
epoch 723 :   146.69400928470156
epoch 724 :   154.38933180354363
epoch 725 :   139.11752693909733
epoch 726 :   131.03274160260813
epoch 727 :   189.0189730595796
epoch 728 :   178.53091186511762
epoch 729 :   163.1476672373317
epoch 730 :   142.64297544600737
epoch 731 :   128.11716185749466
epoch 732 :   136.83137645083772
epoch 733 :   121.41924192417783
epoch 734 :   122.4388979638049
epoch 735 :   169.85563873177958
epoch 736 :   151.76063674293923
epoch 737 :   129.52792486582064
epoch 738 :   108.70872656763629
epoch 739 :   102.7525614397106
epoch 740 :   138.2697728137293
epoch 741 :   111.91631119531486
epoch 742 :   94.52835736905982
epoch 743 :   164.09790162070541
epoch 744 :   127.70558724374699
epoch 745 :   101.00350429652215
epoch 746 :   90.10970480247838
epoch 747 :   96.93143971155395
epoch 748 :   90.13637814078223
epoch 749 :   143.32456867872463
epoch 750 :   84.51492085036955
epoch 751 :   148.44882426891465
epoch 752 :   88.8342577996097
epoch 753 :   71.3522864505098
```

```
epoch 754 :   103.51414040559322
epoch 755 :   161.93477290786197
epoch 756 :   91.66505430555681
epoch 757 :   76.83855334047722
epoch 758 :   154.63450286102469
epoch 759 :   92.49427305177014
epoch 760 :   76.67900781351172
epoch 761 :   92.20215625176728
epoch 762 :   59.69493440391055
epoch 763 :   75.52805040994704
epoch 764 :   163.52066366740308
epoch 765 :   75.17587154096012
epoch 766 :   176.61438757350925
epoch 767 :   92.85180559050062
epoch 768 :   64.10451236791923
epoch 769 :   126.48681177709969
epoch 770 :   66.10536851221059
epoch 771 :   60.173437299732925
epoch 772 :   58.71204387432381
epoch 773 :   193.79603231659752
epoch 774 :   96.72198832607884
epoch 775 :   77.40874438142156
epoch 776 :   48.37631819452589
epoch 777 :   122.38807527005088
epoch 778 :   56.045528001436764
epoch 779 :   133.35268464632873
epoch 780 :   59.760472175719066
epoch 781 :   30.836265500012342
epoch 782 :   47.759342283963214
epoch 783 :   46.54761769263891
epoch 784 :   67.69296862391147
epoch 785 :   103.67331795785023
epoch 786 :   36.08745701943293
epoch 787 :   130.05046988854005
epoch 788 :   51.774415563647906
epoch 789 :   29.271750371818094
epoch 790 :   47.352054838674526
epoch 791 :   21.4783427590489
epoch 792 :   80.12992897281212
epoch 793 :   28.47490745891056
epoch 794 :   29.026854495421905
epoch 795 :   42.54173313293042
epoch 796 :   24.00400765607066
epoch 797 :   39.03306624919102
epoch 798 :   28.38324670581524
epoch 799 :   31.146181999902783
epoch 800 :   28.76069057659184
epoch 801 :   27.638057970939727
```

```
epoch 802 :    26.798066796245003
epoch 803 :    26.12963309328024
epoch 804 :    25.565660097836314
epoch 805 :    25.072215369139883
epoch 806 :    24.63150241376434
epoch 807 :    24.232802199131196
epoch 808 :    23.868747540355617
epoch 809 :    23.533817010108773
epoch 810 :    23.223675471641524
epoch 811 :    22.93483432758819
epoch 812 :    22.66444335643515
epoch 813 :    22.41014748495363
epoch 814 :    22.16998235387007
epoch 815 :    21.94229600579118
epoch 816 :    21.725689131223596
epoch 817 :    21.518968809248936
epoch 818 :    21.321112208619997
epoch 819 :    21.131237746814065
epoch 820 :    20.948581917251094
epoch 821 :    20.772480488715146
epoch 822 :    20.602353124528026
epoch 823 :    20.437690710168006
epoch 824 :    20.27804484963332
epoch 825 :    20.1230191148157
epoch 826 :    19.972261723193494
epoch 827 :    19.825459387078755
epoch 828 :    19.68233212910502
epoch 829 :    19.542628898284406
epoch 830 :    19.40612385180753
epoch 831 :    19.272613192235955
epoch 832 :    19.141912469240282
epoch 833 :    19.01385427081259
epoch 834 :    18.888286241722252
epoch 835 :    18.765069377497117
epoch 836 :    18.6440765508638
epoch 837 :    18.525191234738692
epoch 838 :    18.4083063917778
epoch 839 :    18.293323505413685
epoch 840 :    18.180151731389255
epoch 841 :    18.068707152205704
epoch 842 :    17.95891211969956
epoch 843 :    17.850694673368103
epoch 844 :    17.743988023963116
epoch 845 :    17.638730093558774
epoch 846 :    17.534863104635047
epoch 847 :    17.432333211851972
epoch 848 :    17.331090171165883
epoch 849 :    17.231087041700018
```

```
epoch 850 :    17.132279916474488
epoch 851 :    17.034627678635946
epoch 852 :    16.938091780314377
epoch 853 :    16.84263604161031
epoch 854 :    16.748226467562834
epoch 855 :    16.654831081216578
epoch 856 :    16.562419771149088
epoch 857 :    16.47096415203105
epoch 858 :    16.380437436937388
epoch 859 :    16.290814320312258
epoch 860 :    16.202070870574083
epoch 861 :    16.114184431504817
epoch 862 :    16.027133531604477
epoch 863 :    15.940897800737845
epoch 864 :    15.855457893410428
epoch 865 :    15.770795418118434
epoch 866 :    15.686892872252113
epoch 867 :    15.603733582079405
epoch 868 :    15.521301647394088
epoch 869 :    15.439581890430881
epoch 870 :    15.358559808705664
epoch 871 :    15.278221531453765
epoch 872 :    15.198553779376159
epoch 873 :    15.119543827417795
epoch 874 :    15.041179470349972
epoch 875 :    14.963448990906002
epoch 876 :    14.88634113029167
epoch 877 :    14.80984506086105
epoch 878 :    14.733950360789656
epoch 879 :    14.658646990594631
epoch 880 :    14.583925271342144
epoch 881 :    14.509775864417234
epoch 882 :    14.436189752728833
epoch 883 :    14.363158223239287
epoch 884 :    14.290672850709006
epoch 885 :    14.218725482569523
epoch 886 :    14.147308224828569
epoch 887 :    14.076413428929332
epoch 888 :    14.006033679496587
epoch 889 :    13.93616178288425
epoch 890 :    13.866790756488303
epoch 891 :    13.797913818736207
epoch 892 :    13.72952437972918
epoch 893 :    13.661616032467606
epoch 894 :    13.59418254463064
epoch 895 :    13.527217850848192
epoch 896 :    13.460716045464185
epoch 897 :    13.394671375703311
```

```
epoch 898 :    13.329078235269302
epoch 899 :    13.263931158292898
epoch 900 :    13.199224813638944
epoch 901 :    13.134953999528456
epoch 902 :    13.071113638459769
epoch 903 :    13.007698772407709
epoch 904 :    12.944704558280419
epoch 905 :    12.88212626361604
epoch 906 :    12.819959262501257
epoch 907 :    12.758199031704066
epoch 908 :    12.696841146994105
epoch 909 :    12.635881279651187
epoch 910 :    12.575315193138696
epoch 911 :    12.51513873994406
epoch 912 :    12.455347858554417
epoch 913 :    12.395938570593268
epoch 914 :    12.33690697806313
epoch 915 :    12.27824926073595
epoch 916 :    12.219961673638196
epoch 917 :    12.162040544664903
epoch 918 :    12.104482272274709
epoch 919 :    12.047283323307115
epoch 920 :    11.990440230863587
epoch 921 :    11.933949592300744
epoch 922 :    11.87780806728462
epoch 923 :    11.822012375937565
epoch 924 :    11.766559297045953
epoch 925 :    11.711445666349528
epoch 926 :    11.656668374881448
epoch 927 :    11.602224367389718
epoch 928 :    11.548110640798166
epoch 929 :    11.49432424273988
epoch 930 :    11.440862270136025
epoch 931 :    11.387721867826066
epoch 932 :    11.33490022725368
epoch 933 :    11.282394585188579
epoch 934 :    11.230202222504614
epoch 935 :    11.178320462986997
epoch 936 :    11.126746672199129
epoch 937 :    11.07547825636216
epoch 938 :    11.024512661304795
epoch 939 :    10.97384737141067
epoch 940 :    10.923479908641028
epoch 941 :    10.873407831550168
epoch 942 :    10.82362873436825
epoch 943 :    10.774140246085215
epoch 944 :    10.724940029586095
epoch 945 :    10.676025780797543
```

```
epoch 946 :   10.627395227875798
epoch 947 :   10.57904613040562
epoch 948 :   10.53097627864062
epoch 949 :   10.483183492750806
epoch 950 :   10.43566562211013
epoch 951 :   10.388420544588
epoch 952 :   10.341446165885426
epoch 953 :   10.294740418862673
epoch 954 :   10.248301262920867
epoch 955 :   10.202126683367696
epoch 956 :   10.156214690837725
epoch 957 :   10.110563320693094
epoch 958 :   10.065170632480621
epoch 959 :   10.020034709368485
epoch 960 :   9.975153657634369
epoch 961 :   9.930525606134157
epoch 962 :   9.886148705821581
epoch 963 :   9.842021129249895
epoch 964 :   9.798141070114795
epoch 965 :   9.754506742790351
epoch 966 :   9.711116381893568
epoch 967 :   9.667968241851549
epoch 968 :   9.625060596488186
epoch 969 :   9.582391738618094
epoch 970 :   9.53995997965621
epoch 971 :   9.497763649234097
epoch 972 :   9.45580109483434
epoch 973 :   9.414070681427189
epoch 974 :   9.372570791124874
epoch 975 :   9.331299822841892
epoch 976 :   9.290256191965314
epoch 977 :   9.249438330036622
epoch 978 :   9.208844684441008
epoch 979 :   9.168473718104483
epoch 980 :   9.12832390920383
epoch 981 :   9.088393750878744
epoch 982 :   9.048681750958165
epoch 983 :   9.009186431689944
epoch 984 :   8.969906329479397
epoch 985 :   8.930839994638285
epoch 986 :   8.891985991133435
epoch 987 :   8.853342896354162
epoch 988 :   8.814909300869118
epoch 989 :   8.776683808211263
epoch 990 :   8.738665034648177
epoch 991 :   8.700851608973675
epoch 992 :   8.66324217229667
epoch 993 :   8.625835377840684
```

```
epoch 994 :   8.588629890744192
epoch 995 :   8.55162438787303
epoch 996 :   8.514817557629488
epoch 997 :   8.478208099775838
epoch 998 :   8.44179472525303
epoch 999 :   8.40557615601341
```

[454]:
```python
for i in range(1000,1100):
    for input,target in zip(batch_input,batch_target):
        sinrnn.update(input,np.expand_dims(target,axis = 1))
        Loss.append(np.sum(sinrnn.loss))
    print('epoch',i,': ',np.sum(sinrnn.loss))
    sinrnn.loss.clear()
```

```
epoch 1000 :   8.369551124851567
epoch 1001 :   8.333718375240734
epoch 1002 :   8.298076661178376
epoch 1003 :   8.2626247470275
epoch 1004 :   8.227361407370738
epoch 1005 :   8.192285426860868
epoch 1006 :   8.157395600082634
epoch 1007 :   8.122690731409032
epoch 1008 :   8.088169634872038
epoch 1009 :   8.05383113402614
epoch 1010 :   8.019674061825016
epoch 1011 :   7.985697260491291
epoch 1012 :   7.951899581400612
epoch 1013 :   7.9182798849582
epoch 1014 :   7.884837040486128
epoch 1015 :   7.851569926109107
epoch 1016 :   7.818477428645586
epoch 1017 :   7.785558443500238
epoch 1018 :   7.752811874556473
epoch 1019 :   7.7202366634079584
epoch 1020 :   7.68783164261159
epoch 1021 :   7.655595828878558
epoch 1022 :   7.623528129690331
epoch 1023 :   7.59162748985353
epoch 1024 :   7.559892862075372
epoch 1025 :   7.528323206878424
epoch 1026 :   7.496917492514179
epoch 1027 :   7.465674694874331
epoch 1028 :   7.434593797413401
epoch 1029 :   7.40367379106465
epoch 1030 :   7.3729136741597
epoch 1031 :   7.342312452355105
epoch 1032 :   7.311869138552231
epoch 1033 :   7.281582752826394
```

```
epoch 1034 :   7.251452322350665
epoch 1035 :   7.221476881329678
epoch 1036 :   7.191655470923588
epoch 1037 :   7.161987139185431
epoch 1038 :   7.132470940990924
epoch 1039 :   7.103105937973963
epoch 1040 :   7.07389119846139
epoch 1041 :   7.044825797411509
epoch 1042 :   7.01590881635055
epoch 1043 :   6.987139343312101
epoch 1044 :   6.958516472778855
epoch 1045 :   6.930039305621855
epoch 1046 :   6.901706949044912
epoch 1047 :   6.873518516526929
epoch 1048 :   6.845473127768236
epoch 1049 :   6.8175699086318895
epoch 1050 :   6.789807991094798
epoch 1051 :   6.762186513192992
epoch 1052 :   6.73470461896819
epoch 1053 :   6.707361458420271
epoch 1054 :   6.6801561874534165
epoch 1055 :   6.653087967829156
epoch 1056 :   6.626155967117231
epoch 1057 :   6.599359358646694
epoch 1058 :   6.572697321459034
epoch 1059 :   6.546169040263231
epoch 1060 :   6.519773705387875
epoch 1061 :   6.493510512736131
epoch 1062 :   6.467378663743195
epoch 1063 :   6.441377365330209
epoch 1064 :   6.415505829861706
epoch 1065 :   6.389763275103627
epoch 1066 :   6.364148924178853
epoch 1067 :   6.338662005528443
epoch 1068 :   6.3133017528683695
epoch 1069 :   6.288067405150234
epoch 1070 :   6.262958206519575
epoch 1071 :   6.237973406278218
epoch 1072 :   6.213112258843941
epoch 1073 :   6.188374023711059
epoch 1074 :   6.163757965414807
epoch 1075 :   6.1392633534894365
epoch 1076 :   6.11488946243561
epoch 1077 :   6.090635571679436
epoch 1078 :   6.066500965536986
epoch 1079 :   6.0424849331800035
epoch 1080 :   6.018586768597809
epoch 1081 :   5.994805770562401
```

```
epoch 1082 :   5.971141242593151
epoch 1083 :   5.94759249292348
epoch 1084 :   5.924158834464693
epoch 1085 :   5.900839584772832
epoch 1086 :   5.8776340660147595
epoch 1087 :   5.85454160493402
epoch 1088 :   5.83156153281959
epoch 1089 :   5.808693185470748
epoch 1090 :   5.785935903165999
epoch 1091 :   5.763289030630205
epoch 1092 :   5.740751917003277
epoch 1093 :   5.718323915808038
epoch 1094 :   5.696004384918736
epoch 1095 :   5.673792686529069
epoch 1096 :   5.651688187124758
epoch 1097 :   5.629690257447733
epoch 1098 :   5.607798272469859
epoch 1099 :   5.586011611360936
```

```python
[459]:  for i in range(1100,1500):
            for input,target in zip(batch_input,batch_target):
                sinrnn.update(input,np.expand_dims(target,axis = 1))
                Loss.append(np.sum(sinrnn.loss))
            print('epoch',i,': ',np.sum(sinrnn.loss))
            sinrnn.loss.clear()
```

```
epoch 1100 :   5.564329657460245
epoch 1101 :   5.542751798244087
epoch 1102 :   5.5212774252995995
epoch 1103 :   5.499905934293321
epoch 1104 :   5.478636724944222
epoch 1105 :   5.457469200992622
epoch 1106 :   5.436402770172233
epoch 1107 :   5.415436844184663
epoch 1108 :   5.3945708386667075
epoch 1109 :   5.373804173166446
epoch 1110 :   5.35313627111287
epoch 1111 :   5.332566559789582
epoch 1112 :   5.312094470307067
epoch 1113 :   5.2917194375769325
epoch 1114 :   5.271440900282671
epoch 1115 :   5.2512583008548495
epoch 1116 :   5.231171085443072
epoch 1117 :   5.21117870389121
epoch 1118 :   5.1912806097101605
epoch 1119 :   5.171476260051957
epoch 1120 :   5.151765115684695
epoch 1121 :   5.13214664096604
```

```
epoch 1122 :   5.112620303817441
epoch 1123 :   5.093185575700584
epoch 1124 :   5.073841931590739
epoch 1125 :   5.05458884995209
epoch 1126 :   5.035425812713302
epoch 1127 :   5.016352305242855
epoch 1128 :   4.997367816324502
epoch 1129 :   4.978471838132992
epoch 1130 :   4.959663866210089
epoch 1131 :   4.940943399440364
epoch 1132 :   4.92230994002683
epoch 1133 :   4.903762993469823
epoch 1134 :   4.885302068539736
epoch 1135 :   4.866926677257371
epoch 1136 :   4.84863633486762
epoch 1137 :   4.830430559819352
epoch 1138 :   4.812308873739871
epoch 1139 :   4.794270801414079
epoch 1140 :   4.77631587076105
epoch 1141 :   4.758443612812451
epoch 1142 :   4.7406535616889265
epoch 1143 :   4.722945254579484
epoch 1144 :   4.705318231718223
epoch 1145 :   4.687772036363436
epoch 1146 :   4.670306214775401
epoch 1147 :   4.652920316195229
epoch 1148 :   4.635613892823081
epoch 1149 :   4.618386499797712
epoch 1150 :   4.601237695172956
epoch 1151 :   4.584167039901642
epoch 1152 :   4.567174097809238
epoch 1153 :   4.550258435576587
epoch 1154 :   4.5334196227182595
epoch 1155 :   4.516657231562147
epoch 1156 :   4.499970837229959
epoch 1157 :   4.483360017615723
epoch 1158 :   4.466824353367269
epoch 1159 :   4.450363427864629
epoch 1160 :   4.4339768272023585
epoch 1161 :   4.417664140168147
epoch 1162 :   4.4014249582243075
epoch 1163 :   4.385258875488529
epoch 1164 :   4.369165488714068
epoch 1165 :   4.353144397270953
epoch 1166 :   4.337195203127266
epoch 1167 :   4.321317510829596
epoch 1168 :   4.305510927485048
epoch 1169 :   4.2897750627434315
```

```
epoch 1170 :    4.274109528776527
epoch 1171 :    4.258513940262269
epoch 1172 :    4.242987914364825
epoch 1173 :    4.2275310707169975
epoch 1174 :    4.212143031403242
epoch 1175 :    4.196823420940517
epoch 1176 :    4.181571866261294
epoch 1177 :    4.166387996696062
epoch 1178 :    4.151271443955666
epoch 1179 :    4.1362218421134935
epoch 1180 :    4.121238827589754
epoch 1181 :    4.1063220391323645
epoch 1182 :    4.091471117802458
epoch 1183 :    4.076685706955403
epoch 1184 :    4.061965452224264
epoch 1185 :    4.047310001505678
epoch 1186 :    4.0327190049394295
epoch 1187 :    4.018192114895111
epoch 1188 :    4.003728985955499
epoch 1189 :    3.9893292748987474
epoch 1190 :    3.9749926406840674
epoch 1191 :    3.9607187444353813
epoch 1192 :    3.9465072494247533
epoch 1193 :    3.9323578210581758
epoch 1194 :    3.91827012685802
epoch 1195 :    3.904243836449843
epoch 1196 :    3.890278621545488
epoch 1197 :    3.8763741559278193
epoch 1198 :    3.862530115437078
epoch 1199 :    3.8487461779537235
epoch 1200 :    3.835022023385255
epoch 1201 :    3.821357333650484
epoch 1202 :    3.807751792665829
epoch 1203 :    3.7942050863289474
epoch 1204 :    3.780716902506163
epoch 1205 :    3.7672869310172
epoch 1206 :    3.75391486362112
epoch 1207 :    3.7406003940013344
epoch 1208 :    3.727343217753022
epoch 1209 :    3.714143032367846
epoch 1210 :    3.700999537220447
epoch 1211 :    3.687912433555928
epoch 1212 :    3.674881424473868
epoch 1213 :    3.6619062149167223
epoch 1214 :    3.6489865116560396
epoch 1215 :    3.6361220232778364
epoch 1216 :    3.6233124601707005
epoch 1217 :    3.6105575345119445
```

```
epoch 1218 :   3.59785696 02552266
epoch 1219 :   3.5852104531166717
epoch 1220 :   3.572617730562507
epoch 1221 :   3.560078511796227
epoch 1222 :   3.547592517746125
epoch 1223 :   3.535159471052159
epoch 1224 :   3.522779096054087
epoch 1225 :   3.5104511187786422
epoch 1226 :   3.49817526 69270336
epoch 1227 :   3.485951269863543
epoch 1228 :   3.473778858602497
epoch 1229 :   3.461657765796389
epoch 1230 :   3.449587725724787
epoch 1231 :   3.4375684742812824
epoch 1232 :   3.4255997489625294
epoch 1233 :   3.41368128885657
epoch 1234 :   3.4018128346301326
epoch 1235 :   3.3899941285185093
epoch 1236 :   3.378224914313625
epoch 1237 :   3.366504937352934
epoch 1238 :   3.354833944507028
epoch 1239 :   3.3432116841698774
epoch 1240 :   3.3316379062464914
epoch 1241 :   3.3201123621439654
epoch 1242 :   3.308634804758229
epoch 1243 :   3.297204988464076
epoch 1244 :   3.285822669105056
epoch 1245 :   3.2744876039818216
epoch 1246 :   3.2631995518418466
epoch 1247 :   3.251958272869463
epoch 1248 :   3.2407635286747016
epoch 1249 :   3.229615082283295
epoch 1250 :   3.218512698126091
epoch 1251 :   3.2074561420292165
epoch 1252 :   3.1964451812036905
epoch 1253 :   3.1854795842355426
epoch 1254 :   3.1745591210759097
epoch 1255 :   3.163683563030549
epoch 1256 :   3.152852682750689
epoch 1257 :   3.142066254222771
epoch 1258 :   3.1313240527593904
epoch 1259 :   3.12062585498893
epoch 1260 :   3.1099714388464803
epoch 1261 :   3.099360583564215
epoch 1262 :   3.088793069662401
epoch 1263 :   3.0782686789398195
epoch 1264 :   3.067787194463531
epoch 1265 :   3.057348400560824
```

```
epoch 1266 :   3.0469520828106065
epoch 1267 :   3.0365980280328944
epoch 1268 :   3.0262860242809615
epoch 1269 :   3.0160158608312124
epoch 1270 :   3.0057873281759133
epoch 1271 :   2.9956002180129517
epoch 1272 :   2.9854543232387156
epoch 1273 :   2.9753494379373553
epoch 1274 :   2.965285357373807
epoch 1275 :   2.9552618779845994
epoch 1276 :   2.9452787973698724
epoch 1277 :   2.935335914284479
epoch 1278 :   2.925433028629895
epoch 1279 :   2.9155699414459084
epoch 1280 :   2.905746454902088
epoch 1281 :   2.8959623722901657
epoch 1282 :   2.886217498015933
epoch 1283 :   2.8765116375908577
epoch 1284 :   2.866844597623553
epoch 1285 :   2.857216185813559
epoch 1286 :   2.847626210941661
epoch 1287 :   2.838074482863099
epoch 1288 :   2.8285608124998474
epoch 1289 :   2.819085011832748
epoch 1290 :   2.809646893893584
epoch 1291 :   2.800246272757829
epoch 1292 :   2.7908829635371086
epoch 1293 :   2.7815567823714717
epoch 1294 :   2.772267546422419
epoch 1295 :   2.7630150738651835
epoch 1296 :   2.753799183882189
epoch 1297 :   2.7446196966538325
epoch 1298 :   2.7354764333541945
epoch 1299 :   2.7263692161415087
epoch 1300 :   2.7172978681521127
epoch 1301 :   2.7082622134930894
epoch 1302 :   2.6992620772355176
epoch 1303 :   2.6902972854075657
epoch 1304 :   2.6813676649873948
epoch 1305 :   2.672473043895957
epoch 1306 :   2.6636132509916557
epoch 1307 :   2.6547881160618387
epoch 1308 :   2.645997469816973
epoch 1309 :   2.637241143884333
epoch 1310 :   2.628518970800549
epoch 1311 :   2.6198307840055977
epoch 1312 :   2.6111764178361985
epoch 1313 :   2.60255570751963
```

```
epoch 1314 :   2.59396848916666754
epoch 1315 :   2.585414599766269
epoch 1316 :   2.576893877178109
epoch 1317 :   2.56840616012705907
epoch 1318 :   2.5599512881965913
epoch 1319 :   2.55152910182284
epoch 1320 :   2.543139442288296
epoch 1321 :   2.5347821517162306
epoch 1322 :   2.526457073063601
epoch 1323 :   2.51816405011614
epoch 1324 :   2.509902927481639
epoch 1325 :   2.5016735505844596
epoch 1326 :   2.493475765659347
epoch 1327 :   2.4853094197461925
epoch 1328 :   2.4771743606835854
epoch 1329 :   2.4690704371030585
epoch 1330 :   2.4609974984238185
epoch 1331 :   2.452955394846511
epoch 1332 :   2.44494397734856
epoch 1333 :   2.4369630976777548
epoch 1334 :   2.4290126083468873
epoch 1335 :   2.4210923626282845
epoch 1336 :   2.413202214548239
epoch 1337 :   2.4053420188815746
epoch 1338 :   2.3975116311466445
epoch 1339 :   2.3897109075992766
epoch 1340 :   2.381939705228261
epoch 1341 :   2.374197881749516
epoch 1342 :   2.366485295600884
epoch 1343 :   2.3588018059370057
epoch 1344 :   2.3511472726245666
epoch 1345 :   2.343521556235934
epoch 1346 :   2.3359245180461436
epoch 1347 :   2.3283560200253945
epoch 1348 :   2.320815924836157
epoch 1349 :   2.3133040958268345
epoch 1350 :   2.3058203970272566
epoch 1351 :   2.298364693143942
epoch 1352 :   2.290936849555049
epoch 1353 :   2.2835367323053317
epoch 1354 :   2.276164208101788
epoch 1355 :   2.268819144308471
epoch 1356 :   2.2615014089420207
epoch 1357 :   2.2542108706669373
epoch 1358 :   2.2469473987904833
epoch 1359 :   2.239710863258999
epoch 1360 :   2.232501134652188
epoch 1361 :   2.225318084179389
```

```
epoch 1362 :    2.2181615836747257
epoch 1363 :    2.2110315055923033
epoch 1364 :    2.203927723002715
epoch 1365 :    2.1968501095875
epoch 1366 :    2.189798539635829
epoch 1367 :    2.182772888038849
epoch 1368 :    2.175773030286514
epoch 1369 :    2.1687988424628033
epoch 1370 :    2.161850201241747
epoch 1371 :    2.154926983882662
epoch 1372 :    2.1480290682266396
epoch 1373 :    2.1411563326917564
epoch 1374 :    2.1343086562698455
epoch 1375 :    2.1274859185214305
epoch 1376 :    2.1206879995723353
epoch 1377 :    2.113914780109453
epoch 1378 :    2.1071661413767244
epoch 1379 :    2.1004419651713855
epoch 1380 :    2.0937421338398834
epoch 1381 :    2.0870665302741958
epoch 1382 :    2.0804150379082347
epoch 1383 :    2.073787540713357
epoch 1384 :    2.0671839231952407
epoch 1385 :    2.0606040703898776
epoch 1386 :    2.0540478678603082
epoch 1387 :    2.0475152016922933
epoch 1388 :    2.0410059584914197
epoch 1389 :    2.0345200253789777
epoch 1390 :    2.028057289988926
epoch 1391 :    2.02161764046405
epoch 1392 :    2.0152009654528724
epoch 1393 :    2.008807154106258
epoch 1394 :    2.0024360960738217
epoch 1395 :    1.9960876815006405
epoch 1396 :    1.989761801023987
epoch 1397 :    1.9834583457704886
epoch 1398 :    1.9771772073529434
epoch 1399 :    1.9709182778666483
epoch 1400 :    1.9646814498865073
epoch 1401 :    1.9584666164645357
epoch 1402 :    1.9522736711262465
epoch 1403 :    1.9461025078685168
epoch 1404 :    1.939953021155704
epoch 1405 :    1.9338251059177025
epoch 1406 :    1.9277186575469607
epoch 1407 :    1.9216335718955802
epoch 1408 :    1.9155697452728375
epoch 1409 :    1.9095270744424249
```

```
epoch 1410 :    1.9035054566199667
epoch 1411 :    1.8975047894713781
epoch 1412 :    1.8915249711092288
epoch 1413 :    1.8855659000909268
epoch 1414 :    1.879627475417039
epoch 1415 :    1.8737095965281014
epoch 1416 :    1.8678121633033995
epoch 1417 :    1.8619350760579467
epoch 1418 :    1.8560782355419387
epoch 1419 :    1.8502415429375165
epoch 1420 :    1.844424899857752
epoch 1421 :    1.8386282083448957
epoch 1422 :    1.8328513708679117
epoch 1423 :    1.8270942903220893
epoch 1424 :    1.8213568700274463
epoch 1425 :    1.8156390137264964
epoch 1426 :    1.8099406255838442
epoch 1427 :    1.8042616101849385
epoch 1428 :    1.7986018725346222
epoch 1429 :    1.792961318056821
epoch 1430 :    1.7873398525934308
epoch 1431 :    1.7817373824033336
epoch 1432 :    1.7761538141622617
epoch 1433 :    1.7705890549623322
epoch 1434 :    1.7650430123116445
epoch 1435 :    1.7595155941341
epoch 1436 :    1.754006708769302
epoch 1437 :    1.7485162649734571
epoch 1438 :    1.7430441719182983
epoch 1439 :    1.7375903391925538
epoch 1440 :    1.7321546768024603
epoch 1441 :    1.7267370951718202
epoch 1442 :    1.7213375051440678
epoch 1443 :    1.7159558179824885
epoch 1444 :    1.7105919453721834
epoch 1445 :    1.7052457994210526
epoch 1446 :    1.6999172926618806
epoch 1447 :    1.69460633805454
epoch 1448 :    1.6893128489874651
epoch 1449 :    1.6840367392806959
epoch 1450 :    1.6787779231883153
epoch 1451 :    1.673536315401407
epoch 1452 :    1.6683118310509435
epoch 1453 :    1.663104385711652
epoch 1454 :    1.657913895405572
epoch 1455 :    1.6527402766055306
epoch 1456 :    1.6475834462403738
epoch 1457 :    1.6424433216992047
```

```
epoch 1458 :   1.6373198208357933
epoch 1459 :   1.6322128619747587
epoch 1460 :   1.6271223639165868
epoch 1461 :   1.6220482459437822
epoch 1462 :   1.6169904278270144
epoch 1463 :   1.6119488298326785
epoch 1464 :   1.6069233727291086
epoch 1465 :   1.6019139777949576
epoch 1466 :   1.5969205668262525
epoch 1467 :   1.5919430621457806
epoch 1468 :   1.5869813866118767
epoch 1469 :   1.5820354636275753
epoch 1470 :   1.5771052171506612
epoch 1471 :   1.572190571704498
epoch 1472 :   1.5672914523882413
epoch 1473 :   1.562407784889415
epoch 1474 :   1.5575394954949937
epoch 1475 :   1.5526865111052788
epoch 1476 :   1.5478487592464512
epoch 1477 :   1.5430261680850925
epoch 1478 :   1.5382186664425286
epoch 1479 :   1.5334261838104906
epoch 1480 :   1.5286486503670074
epoch 1481 :   1.5238859969936924
epoch 1482 :   1.5191381552925303
epoch 1483 :   1.5144050576051955
epoch 1484 :   1.5096866370317081
epoch 1485 :   1.5049828274506039
epoch 1486 :   1.5002935635399324
epoch 1487 :   1.495618780798869
epoch 1488 :   1.490958415570692
epoch 1489 :   1.4863124050663288
epoch 1490 :   1.4816806873888058
epoch 1491 :   1.4770632015591196
epoch 1492 :   1.4724598875429828
epoch 1493 :   1.4678706862782391
epoch 1494 :   1.463295539704091
epoch 1495 :   1.4587343907906054
epoch 1496 :   1.454187183569989
epoch 1497 :   1.4496538631683722
epoch 1498 :   1.4451343758401491
epoch 1499 :   1.4406286690017487
```

[458]:
```python
#parameters = np.ones((3,1))
T = 50
parameters = np.array([6,0,1]).reshape(3,1)
x = np.tile(parameters,(T))
```
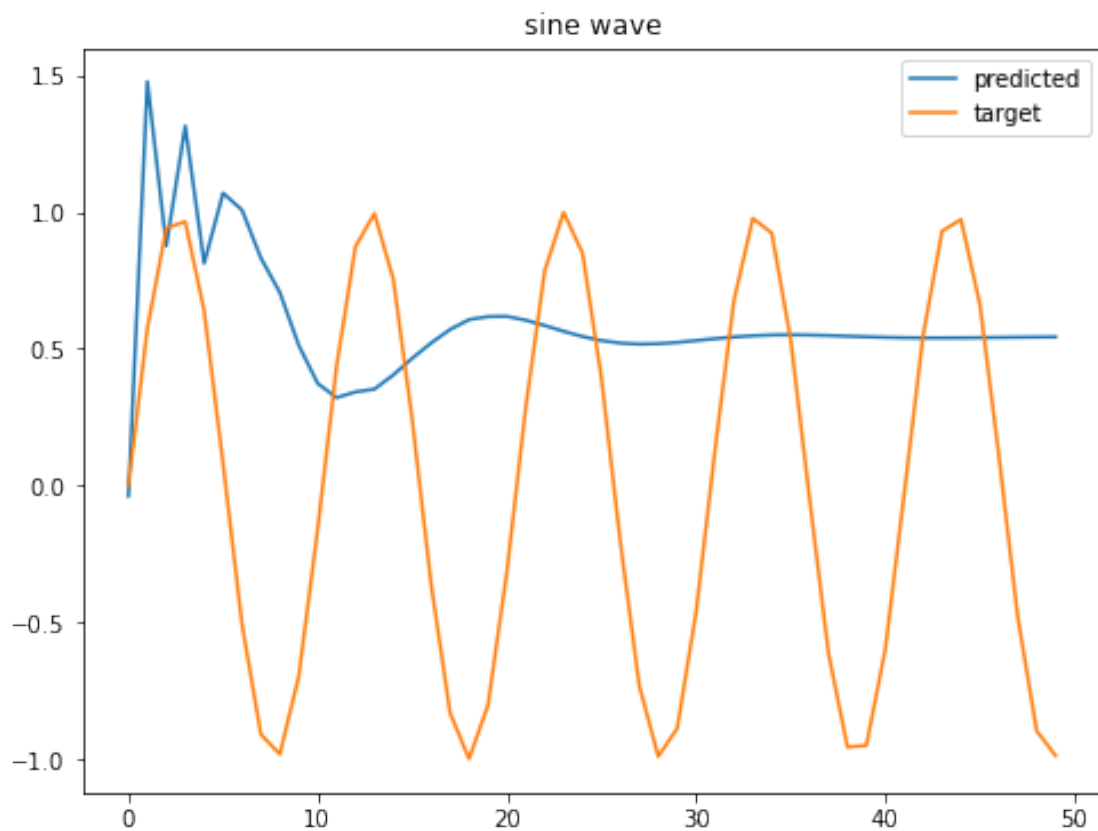
```
time = np.linspace(0, 5, T)
frequency = x[0][0]
theta = x[1][0]
amplitude = x[2][0]
y = amplitude * np.sin(frequency * time + theta)


predicted = sinrnn.forward(x)
target = y
plt.figure(figsize = (8, 6))
plt.plot(predicted, label = 'predicted', markersize = 3)
plt.plot(target, label = 'target', markersize = 3)
plt.title("sine wave")
plt.legend()
plt.show()
```

50

[390]:
```
parameters = np.random.randint(3,5)
fix = np.array([0,1])
x = np.insert(fix,0,parameters).reshape(3,1)
```

[390]: 3

[395]: ```python
x = np.insert(fix,0,parameters).reshape(3,1)
```

[396]: ```python
x.shape
```

[396]: (3, 1)

[ ]: