

# Batch RNN

June 28, 2022

```
[470]: 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
```

```
[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)
```

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

[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))

        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)
        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

```

```

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)
            x_hid = aprox1_w_hidden @ hidden_state_1 + self.b_hidden

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        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)
    hidden_state_2 = hid_out

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```

        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 = []
    y_out = []

```

```

dldw_in = np.zeros((batch_size,) + self.w_in.shape)
dldw_hidden = np.zeros((batch_size,) + self.w_hidden.shape)
dlldb_hidden = np.zeros((batch_size,) + self.b_hidden.shape)
dldw_out = np.zeros((batch_size,) + self.w_out.shape)
dlldb_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):

    dlldb_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])
    dlldb_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)

```

```

[498]: input = []
target = []
T = 50
Num = 50

for i in range(Num):

    parameters = np.random.uniform(1,5,(3,1))
    #p = np.random.uniform(1,5)
    #fix = np.array([0.0,1.0])
    #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)

```

```

[499]: %%time
sinrnn = RNN(3,100,1,0.0001)
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 : 4787.912300799155
epoch 1 : 2508.925904918954
epoch 2 : 2444.039932361883
epoch 3 : 2409.4373528177694
epoch 4 : 2388.4464974367384
epoch 5 : 2373.8753072391446
epoch 6 : 2362.50615511201
epoch 7 : 2352.845513223304
epoch 8 : 2344.185406945141
epoch 9 : 2336.191524411885
epoch 10 : 2328.713313090646
epoch 11 : 2321.6898473018114
epoch 12 : 2315.0976867998556
epoch 13 : 2308.920725799907
epoch 14 : 2303.1362906960403
epoch 15 : 2297.713237147501
epoch 16 : 2292.6157880210935
epoch 17 : 2287.8079119471363
epoch 18 : 2283.256097046472
epoch 19 : 2278.930495496948
epoch 20 : 2274.805060977592
epoch 21 : 2270.857222441968
epoch 22 : 2267.0674149084316
epoch 23 : 2263.418619743644
epoch 24 : 2259.8959720480448
epoch 25 : 2256.486446956731
epoch 26 : 2253.1786175159027
epoch 27 : 2249.962470600685
epoch 28 : 2246.8292668710837
epoch 29 : 2243.7714324475137
epoch 30 : 2240.78247215
epoch 31 : 2237.856896070286
epoch 32 : 2234.9901527216234

```

epoch 33 : 2232.1785631086686  
epoch 34 : 2229.419251011135  
epoch 35 : 2226.7100658674412  
epoch 36 : 2224.0494961078907  
epoch 37 : 2221.436572680645  
epoch 38 : 2218.8707646612584  
epoch 39 : 2216.3518708493407  
epoch 40 : 2213.8799126621466  
epoch 41 : 2211.4550340662877  
epoch 42 : 2209.077413639293  
epoch 43 : 2206.74719232785  
epoch 44 : 2204.464418502411  
epoch 45 : 2202.2290099924767  
epoch 46 : 2200.040731311262  
epoch 47 : 2197.899183430099  
epoch 48 : 2195.8038032252457  
epoch 49 : 2193.7538699369434  
epoch 50 : 2191.7485164451837  
epoch 51 : 2189.786743692677  
epoch 52 : 2187.8674370485105  
epoch 53 : 2185.989383749911  
epoch 54 : 2184.1512907825277  
epoch 55 : 2182.3518026905476  
epoch 56 : 2180.5895188850873  
epoch 57 : 2178.8630100757427  
epoch 58 : 2177.170833507313  
epoch 59 : 2175.5115467504497  
epoch 60 : 2173.88371987103  
epoch 61 : 2172.2859458828143  
epoch 62 : 2170.716849464314  
epoch 63 : 2169.1750939876183  
epoch 64 : 2167.6593869601734  
epoch 65 : 2166.1684840185926  
epoch 66 : 2164.701191636904  
epoch 67 : 2163.2563687219686  
epoch 68 : 2161.832927268712  
epoch 69 : 2160.4298322399495  
epoch 70 : 2159.046100822585  
epoch 71 : 2157.680801195958  
epoch 72 : 2156.3330509308316  
epoch 73 : 2155.002015120302  
epoch 74 : 2153.6869043274846  
epoch 75 : 2152.3869724199485  
epoch 76 : 2151.1015143475556  
epoch 77 : 2149.8298639089357  
epoch 78 : 2148.5713915420906  
epoch 79 : 2147.325502166556  
epoch 80 : 2146.0916330979026

epoch 81 : 2144.869252050062  
epoch 82 : 2143.6578552366523  
epoch 83 : 2142.456965579155  
epoch 84 : 2141.2661310271174  
epoch 85 : 2140.0849229934893  
epoch 86 : 2138.9129349065392  
epoch 87 : 2137.7497808784574  
epoch 88 : 2136.5950944896335  
epoch 89 : 2135.4485276866553  
epoch 90 : 2134.3097497912086  
epoch 91 : 2133.1784466162962  
epoch 92 : 2132.054319685496  
epoch 93 : 2130.9370855503107  
epoch 94 : 2129.826475200114  
epoch 95 : 2128.72223355867  
epoch 96 : 2127.624119060793  
epoch 97 : 2126.5319033024252  
epoch 98 : 2125.445370757141  
epoch 99 : 2124.3643185520364  
epoch 100 : 2123.2885562958786  
epoch 101 : 2122.217905952469  
epoch 102 : 2121.152201752283  
epoch 103 : 2120.0912901355455  
epoch 104 : 2119.035029720072  
epoch 105 : 2117.9832912873076  
epoch 106 : 2116.9359577800687  
epoch 107 : 2115.892924305524  
epoch 108 : 2114.854098136935  
epoch 109 : 2113.819398707577  
epoch 110 : 2112.7887575901655  
epoch 111 : 2111.762118454967  
epoch 112 : 2110.7394369996546  
epoch 113 : 2109.7206808438755  
epoch 114 : 2108.705829381517  
epoch 115 : 2107.694873583735  
epoch 116 : 2106.6878157460887  
epoch 117 : 2105.684669173558  
epoch 118 : 2104.68545779785  
epoch 119 : 2103.6902157222776  
epoch 120 : 2102.6989866905787  
epoch 121 : 2101.7118234773543  
epoch 122 : 2100.7287871993376  
epoch 123 : 2099.7499465484098  
epoch 124 : 2098.775376949116  
epoch 125 : 2097.8051596453693  
epoch 126 : 2096.839380722991  
epoch 127 : 2095.8781300766395  
epoch 128 : 2094.921500331479

epoch 129 : 2093.969585731537  
epoch 130 : 2093.0224810080476  
epoch 131 : 2092.080280242087  
epoch 132 : 2091.143075736447  
epoch 133 : 2090.210956911938  
epoch 134 : 2089.2840092431056  
epoch 135 : 2088.3623132477164  
epoch 136 : 2087.4459435433555  
epoch 137 : 2086.534967983068  
epoch 138 : 2085.629446880268  
epoch 139 : 2084.729432331198  
epoch 140 : 2083.834967641089  
epoch 141 : 2082.9460868579713  
epoch 142 : 2082.0628144158904  
epoch 143 : 2081.1851648871334  
epoch 144 : 2080.3131428410948  
epoch 145 : 2079.446742805616  
epoch 146 : 2078.5859493250814  
epoch 147 : 2077.7307371082916  
epoch 148 : 2076.881071258147  
epoch 149 : 2076.036907574467  
epoch 150 : 2075.198192920876  
epoch 151 : 2074.3648656465098  
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epoch 494 : 1746.7518757887249
epoch 495 : 2170.434602152525
epoch 496 : 2099.2634288593745
epoch 497 : 2048.1237952252623
epoch 498 : 1984.1090524116644
epoch 499 : 1681.2550830996406
CPU times: user 12min 9s, sys: 1.36 s, total: 12min 11s
Wall time: 12min 11s

```

```

[500]: 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 : 1529.30639154939
epoch 501 : 1449.670315262736
epoch 502 : 1397.1673021159866

```

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epoch 983 : 45.82241424134108
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epoch 985 : 64.82162165205176
epoch 986 : 56.28638565541442
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epoch 993 : 66.5855260321866
epoch 994 : 48.41724965631692
epoch 995 : 54.263615733872456
epoch 996 : 51.337268059120916
epoch 997 : 59.10242995460235
epoch 998 : 51.687449303848105
epoch 999 : 53.282404318895956

```

```

[501]: for i in range(1000,1500):
        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 1000 : 61.449564969513524
epoch 1001 : 49.12236218666301
epoch 1002 : 43.91846984539545
epoch 1003 : 42.41289665241604
epoch 1004 : 44.42458350554401
epoch 1005 : 47.50018008050273
epoch 1006 : 56.45920625623115
epoch 1007 : 47.07489052492114
epoch 1008 : 70.51831444700437
epoch 1009 : 82.5116372100909
epoch 1010 : 61.71980482884465
epoch 1011 : 69.36612154833213
epoch 1012 : 76.50319583838908
epoch 1013 : 56.778022862037744
epoch 1014 : 55.69236811040177
epoch 1015 : 56.53016917875581
epoch 1016 : 51.31811140725671
epoch 1017 : 44.15186652080917
epoch 1018 : 42.811696216872406
epoch 1019 : 45.534631095244485
epoch 1020 : 51.22798729163567
epoch 1021 : 62.23242900608588
epoch 1022 : 48.45176362649585

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epoch 1023 : 65.15761487970751  
epoch 1024 : 62.74231103679758  
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epoch 1027 : 46.89283366413072  
epoch 1028 : 48.19296153377104  
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epoch 1498 : 35.84331260462648  
epoch 1499 : 33.38044614994269



```
[502]: for i in range(1500,2000):
        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()
```

```
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epoch 1501 : 37.04581707153115
epoch 1502 : 30.348165551732535
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epoch 1998 : 25.358464087991354
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[511]: for i in range(2000,2500):
        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()

```

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epoch 2001 : 24.280868663022755
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epoch 2497 : 27.514379379737683
epoch 2498 : 26.199448885517615
epoch 2499 : 24.660317584444762
```

```
[527]: for i in range(2500,3000):
        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 2500 : 23.107064410580122
epoch 2501 : 21.49610052061891
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epoch 2503 : 19.02901131004393
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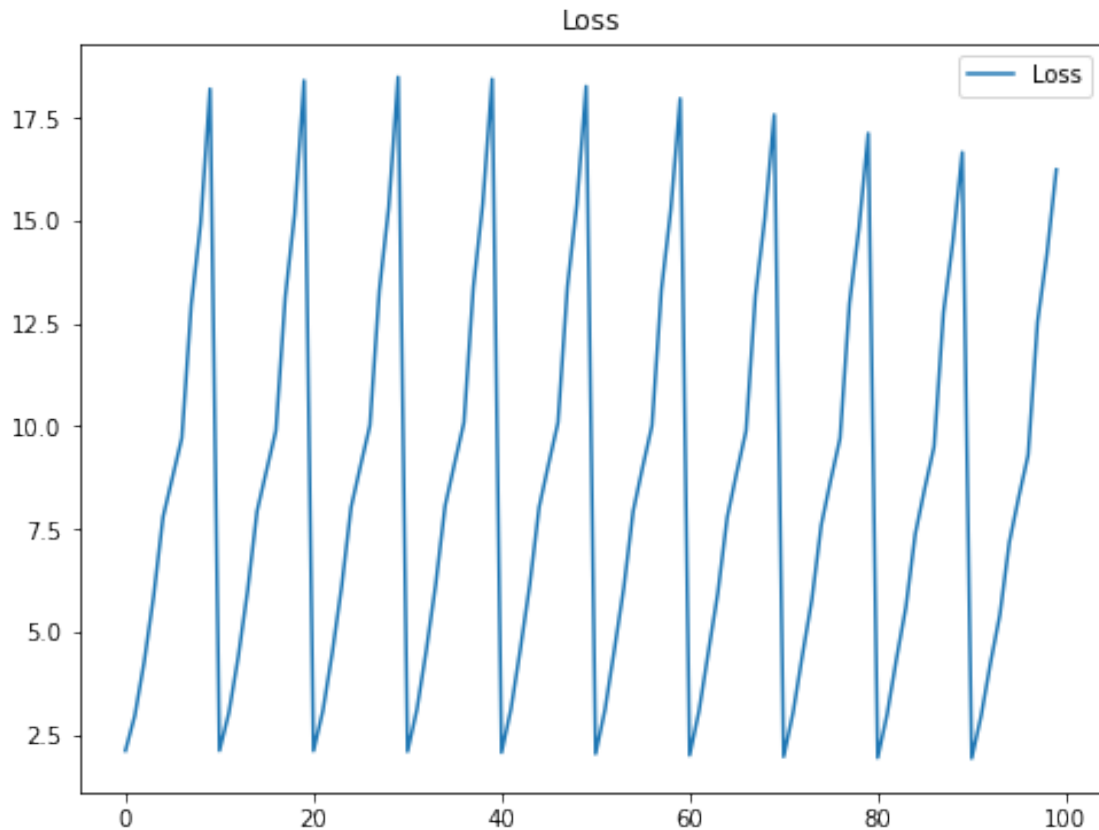
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```

```
[528]: plt.figure(figsize = (8, 6))
plt.plot(Loss[-100:], label = 'Loss', markersize = 3)
plt.title("Loss")
plt.legend()
plt.show()
```



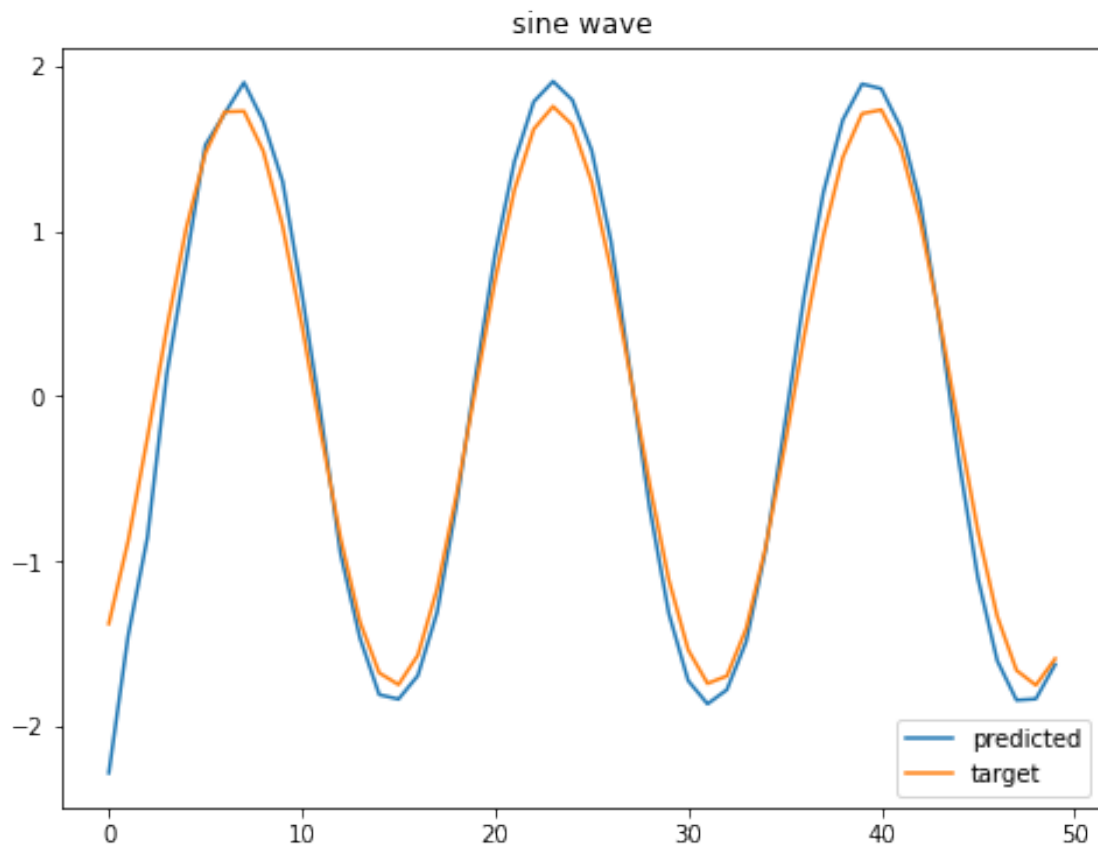


```
[543]: T = 50
parameters = np.random.uniform(1,8,(3,1))
x = np.tile(parameters,(T))
time = np.linspace(0, 5, T)
frequency = x[0][0]
theta = x[1][0]
amplitude = x[2][0]
y = amplitude * np.sin(frequency * time + theta)

print(parameters)

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()
```

```
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50
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[ ]:
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