Task3

May 17, 2023

[1]:
```
import string
import random
import torch
import torch.nn as nn
import matplotlib.pyplot as plt
import numpy as np
```

Prepare for Dataset

[2]:
```
# Get a random sequence of sine curve.
def get_random_seq():
    seq_len     = 128  # The length of an input sequence.
    # Sample a sequence.
    t = np.arange(0, seq_len)
    a = 2*np.pi*1.0/seq_len
    b = 2*np.pi*np.random.rand()*5
    seq = np.sin(a*t+b)
    return seq

# Sample a mini-batch including input tensor and target tensor.
def get_input_and_target():
    seq    = get_random_seq()
    input  = torch.tensor(seq[:-1]).float().view(-1,1,1) # Input sequence.
    target = torch.tensor(seq[1:]).float().view(-1,1,1)  # Target sequence.
    return input, target
```

Choose a Device

[3]:
```
# If there are GPUs, choose the first one for computing. Otherwise use CPU.
device = torch.device("cuda:0" if torch.cuda.is_available() else "cpu")
print(device)
# If 'cuda:0' is printed, it means GPU is available.
```

```
cuda:0
```

Network Definition

[4]:
```
class Net(nn.Module):
    def __init__(self):
```

```python
        # Initialization.
        super(Net, self).__init__()
        self.input_size  = 1
        self.hidden_size = 100       # Hidden size: 100.
        self.output_size = 1

        self.rnn = nn.RNNCell(self.input_size, self.hidden_size)
        self.linear = nn.Linear(self.hidden_size, self.output_size)

    def forward(self, input, hidden):
        """ Forward function.
              input:  Input. It refers to the x_t in homework write-up.
              hidden: Previous hidden state. It refers to the h_{t-1}.
            Returns (output, hidden) where output refers to y_t and
                     hidden refers to h_t.
        """
        # Forward function.
        hidden = self.rnn(input, hidden)
        output = self.linear(hidden)

        return output, hidden

    def init_hidden(self):
        # Initial hidden state.
        # 1 means batch size = 1.
        return torch.zeros(1, self.hidden_size).to(device)

net = Net()     # Create the network instance.
net.to(device)  # Move the network parameters to the specified device.
```

[4]:
```
Net(
  (rnn): RNNCell(1, 100)
  (linear): Linear(in_features=100, out_features=1, bias=True)
)
```

Training Step and Evaluation Step

[5]:
```python
# Training step function.
def train_step(net, opt, input, target):
    """ Training step.
        net:    The network instance.
        opt:    The optimizer instance.
        input:  Input tensor.  Shape: [seq_len, 1, 1].
        target: Target tensor. Shape: [seq_len, 1].
    """
    seq_len = input.shape[0]    # Get the sequence length of current input.
    hidden = net.init_hidden()  # Initial hidden state.
```

```python
    net.zero_grad()              # Clear the gradient.
    loss = 0                     # Initial loss.

    for t in range(seq_len):     # For each one in the input sequence.
        output, hidden = net(input[t], hidden)
        loss += loss_func(output, target[t])

    loss.backward()              # Backward.
    opt.step()                   # Update the weights.

    return loss / seq_len        # Return the average loss w.r.t sequence length.
```

[6]:
```python
# Evaluation step function.
def eval_step(net, predicted_len=100):
    # Initialize the hidden state, input and the predicted sequence.
    hidden        = net.init_hidden()
    init_seq      = get_random_seq()
    init_input    = torch.tensor(init_seq).float().view(-1,1,1).to(device)
    predicted_seq = []

    # Use initial points on the curve to "build up" hidden state.
    for t in range(len(init_seq) - 1):
        output, hidden = net(init_input[t], hidden)

    # Set current input as the last character of the initial string.
    input = init_input[-1]

    # Predict more points after the initial string.
    for t in range(predicted_len):
        # Get the current output and hidden state.
        output, hidden = net(input, hidden)

        # Add predicted point to the sequence and use it as next input.
        predicted_seq.append(output.item())

        # Use the predicted point to generate the input of next round.
        input = output

    return init_seq, predicted_seq
```

Training Procedure

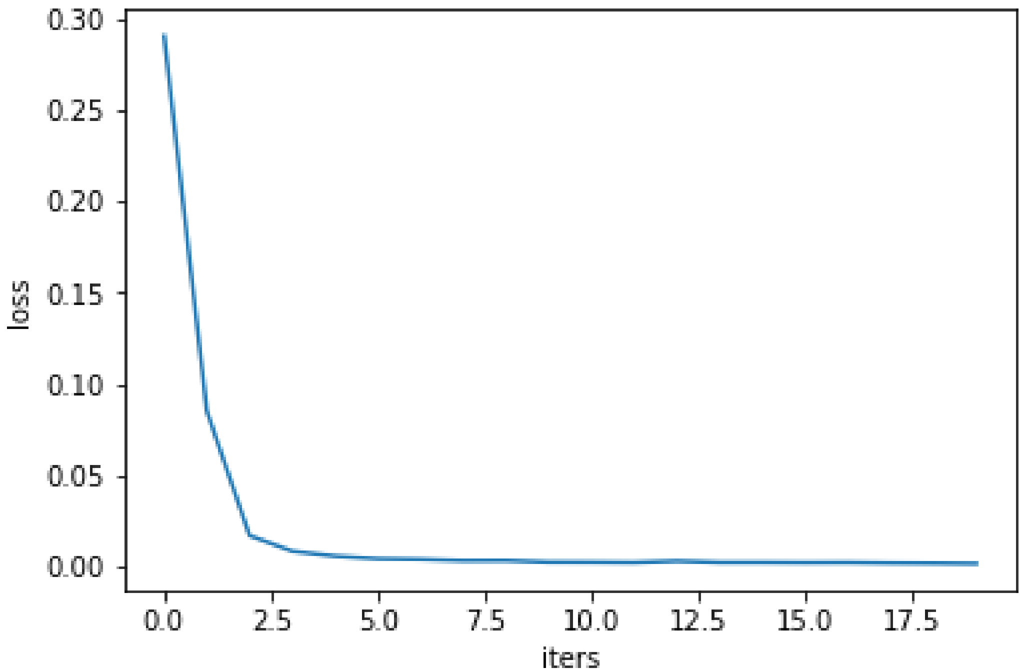
[7]:
```python
# Number of iterations.
iters       = 200     # Number of training iterations.
print_iters = 10      # Number of iterations for each log printing.

# The loss variables.
```

```python
all_losses = []
loss_sum   = 0

# Initialize the optimizer and the loss function.
opt       = torch.optim.Adam(net.parameters(), lr=0.005)
loss_func = nn.MSELoss()

# Training procedure.
for i in range(iters):
    input, target = get_input_and_target()             # Fetch input and target.
    input, target = input.to(device), target.to(device) # Move to GPU memory.
    loss      = train_step(net, opt, input, target)   # Calculate the loss.
    loss_sum += loss                                  # Accumulate the loss.

    # Print the log.
    if i % print_iters == print_iters - 1:
        print('iter:{}/{} loss:{}'.format(i, iters, loss_sum / print_iters))
        #print('generated sequence: {}\n'.format(eval_step(net)))

        # Track the loss.
        all_losses.append(loss_sum / print_iters)
        loss_sum = 0
all_losses = [loss.cpu().item() for loss in all_losses]
```

```
iter:9/200 loss:0.29096028208732605
iter:19/200 loss:0.08517087250947952
iter:29/200 loss:0.016879333183169365
iter:39/200 loss:0.008299930952489376
iter:49/200 loss:0.005581032019108534
iter:59/200 loss:0.004171126987785101
iter:69/200 loss:0.003838139120489359
iter:79/200 loss:0.003137431340292096
iter:89/200 loss:0.0031852182000875473
iter:99/200 loss:0.0023043795954436064
iter:109/200 loss:0.0022559163626283407
iter:119/200 loss:0.0020954618230462074
iter:129/200 loss:0.002896891674026847
iter:139/200 loss:0.0021398861426860094
iter:149/200 loss:0.002140552271157503
iter:159/200 loss:0.0020387633703649044
iter:169/200 loss:0.0020962313283234835
iter:179/200 loss:0.0018392304191365838
iter:189/200 loss:0.0017137483227998018
iter:199/200 loss:0.0014735352015122771
```

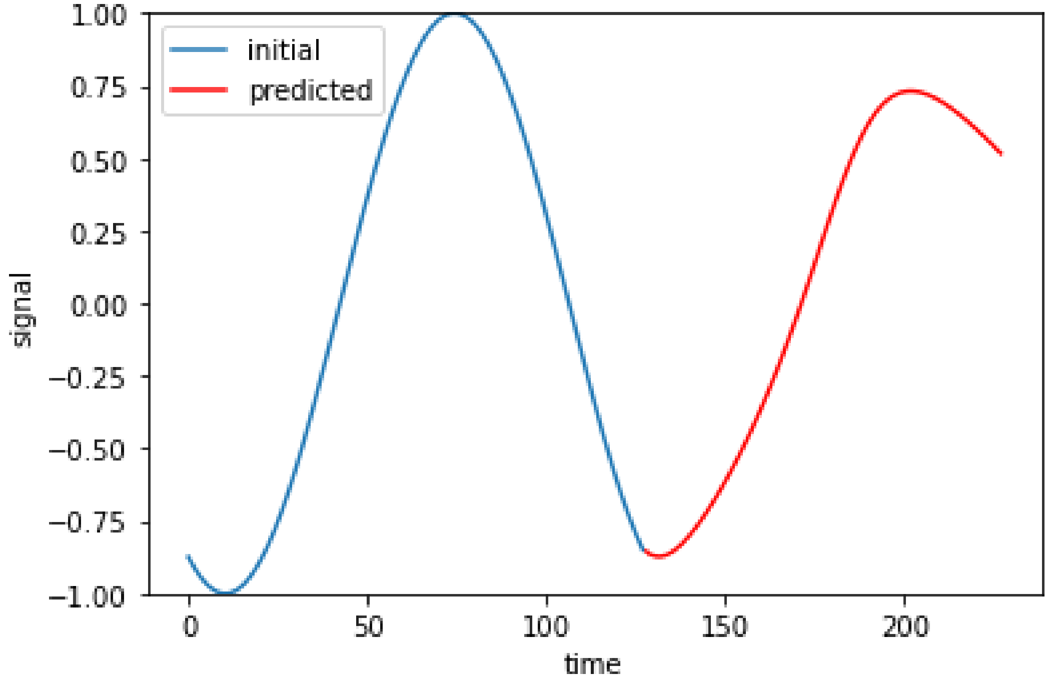
Training Loss Curve

[8]:
```
plt.xlabel('iters')
plt.ylabel('loss')
plt.plot(all_losses)
plt.show()
```



Evaluation: A Sample of Generated Sequence

[9]:
```
init_seq, predicted_seq = eval_step(net, predicted_len=100)
init_t      = np.arange(0, len(init_seq))
predicted_t = np.arange(len(init_seq), len(init_seq)+len(predicted_seq))
plt.plot(init_t, init_seq, label='initial')
plt.plot(predicted_t, predicted_seq, color='red', label='predicted')
plt.legend()
plt.ylim([-1, 1])
plt.xlabel('time')
plt.ylabel('signal')
plt.show()
```



1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
signal
0
50
100
150
200
time
initial
predicted