vanillla_rnn

April 22, 2019

```
In [0]: import numpy as np
        import matplotlib.pyplot as plt
        # Load the Drive helper and mount
        from google.colab import drive

In [2]: # This will prompt for authorization.
        drive.mount('/content/drive')
```

```
Drive already mounted at /content/drive; to attempt to forcibly remount, call drive.mount("/co
'/content/drive/My Drive/speeches.txt'
```

```
In [0]: # softmax of a numpy array
        def softmax(x):
            e_x = np.exp(x - np.max(x))
            return e_x / e_x.sum(axis=0)

In [0]: # forward pass for one-to-one RNN architecture
        def forward_pass(X, Y, h_init, parameters):

            # dictionaries to store values at each time step
            h = {} # to keep hidden states
            x = {} # to keep input states
            y = {} # to keep softmax output (array of probs with vocab size)

            # retrieve the model parameters
            W_xh,W_hh,W_hy,b_h,b_y = parameters

            # set initial hidden state to start RNN loop
            h[-1] = np.copy(h_init)
            loss = 0

            # for each character in the input/output
            for t in range(len(X)):

                # one hot representation of character t
                x[t] = np.zeros((vocab_size,1))
                x[t][X[t]] = 1
```

```
        # rnn cell calculations given by formula
        h[t] = np.tanh(np.dot(W_hh,h[t-1]) + np.dot(W_xh,x[t]) + b_h)
        y[t] = softmax(np.dot(W_hy,h[t]) + b_y)

        # get the softmax probability of output character t
        softmax_out = y[t][Y[t],0]

        # update the cross entropy (softmax) loss at each time step
        loss += -np.log(softmax_out)

    return loss, y, x, h, h[len(X)-1] # rnn input and hidden states are needed for bac
```

In [0]:
```
def backward_pass(X, Y, parameters,y,x,h):

    # retrieve model parameters
    W_xh,W_hh,W_hy,b_h,b_y = parameters

    # initialize the gradients of same shape with parameters
    dW_xh,dW_hh,dW_hy,db_h,db_y = np.zeros(W_xh.shape),np.zeros(W_hh.shape),np.zeros(W
    dh_next = np.zeros(h[0].shape)

    # backpropagation for each time step
    for t in reversed(range(len(X))):

        # calculate gradients for all parameters
        d_y = np.copy(y[t])
        d_y[Y[t]] = d_y[Y[t]] - 1
        dW_hy += np.dot(d_y,h[t].T)
        db_y += d_y
        d_h = np.dot(W_hy.T, d_y) + dh_next
        d_tanh = (1- h[t]*h[t]) *d_h # derivative of tanh (1-t2)dt
        db_h += d_tanh
        dW_xh += np.dot(d_tanh, x[t].T)
        dW_hh += np.dot(d_tanh, h[t-1].T)
        dh_next = np.dot(W_hh.T,d_tanh)

    return (dW_xh,dW_hh,dW_hy,db_h,db_y)
```

In [0]:
```
def SGD(X, Y, h_init, parameters, learning_rate):

    loss, y_preds, x, h, h_init = forward_pass(X,Y,h_init,parameters)
    gradients = backward_pass(X,Y,parameters,y_preds,x,h)
    #gradients = gradient_clip(gradients)

    new_params = []
    for i in range(len(parameters)):
```

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            new_params.append(parameters[i] - learning_rate * gradients[i] )
        return tuple(new_params), h_init, loss
```

In [0]:
```
def initialize_parameters(num_hiddens,vocab_size):

    # weight matrices
    W_hx = np.random.randn(num_hiddens, vocab_size) * 0.01
    W_hh = np.random.randn(num_hiddens, num_hiddens) * 0.01
    W_yh = np.random.randn(vocab_size, num_hiddens) * 0.01

    # biases
    b_h = np.zeros((num_hiddens, 1))
    b_y = np.zeros((vocab_size, 1))

    return (W_hx,W_hh,W_yh,b_h,b_y)
```

In [0]:
```
def train(data, num_hiddens, vocab_size, batch_size, learning_rate, num_epoch, char_to_

    num_iteration = int((len(data)/batch_size) * num_epoch) # total number of iteratio
    parameters = initialize_parameters(num_hiddens,vocab_size) # get model parameters
    h_init = np.zeros((num_hiddens, 1)) # get initial hidden vector
    smooth_loss = -np.log(1.0/vocab_size)*batch_size # smooth loss not to see high oss

    losses = []
    cnt = 1
    epoch_cnt = 1
    for i in range(num_iteration):

        # get batch of training data
        X_batch = []
        Y_batch = []
        for j in range(batch_size):
            X_batch.append(char_to_index[data[cnt-1]])
            Y_batch.append(char_to_index[data[cnt]])
            cnt+=1

        # forward/backward pass and update parameters
        parameters, h_init, loss = SGD(X_batch, Y_batch, h_init, parameters, learning_r
        smooth_loss = smooth_loss * 0.999 + loss * 0.001
        losses.append(smooth_loss)

        # epoch is completed print progress and reset counter
        if (len(data) - cnt) <= batch_size or (i == 0):
            print ("Epoch:", epoch_cnt,"\tBatch:", str(cnt-1) + "/" + str(len(data)), '
            cnt = 1
            epoch_cnt+=1

    return parameters,h_init,losses
```

```
In [0]: def sampling(parameters, h_init, sample_size, index_to_char):

            # retrieve model parameters
            W_xh,W_hh,W_hy,b_h,b_y = parameters

            # get the hyper parameters
            vocab_size = b_y.shape[0]
            num_hiddens = W_hh.shape[1]

            # initialize the sequence and first hidden state
            x = np.zeros((vocab_size,1))
            #h_init = np.zeros((num_hiddens,1))
            # store all sampled indices
            indices = []

            for i in range(sample_size):

                # make forward pass
                h_init = np.tanh(np.dot(W_hh,h_init) + np.dot(W_xh,x) + b_h)
                y = softmax(np.dot(W_hy,h_init) + b_y)

                # get a random index in vocab within the probability distribution of y (ravel(
                index = np.random.choice(range(vocab_size), p=y.ravel())

                # add the sampled char into one hot vector
                x = np.zeros((vocab_size, 1))
                x[index] = 1

                # append chosen index at each iteration
                indices.append(index)

            sampled_text = ''
            for index in indices:
                sampled_text += index_to_char[index]

            return sampled_text

In [0]: def data_preprocess(file_path):
            data = open(file_path, 'r',encoding = 'utf-8').read()
            data = data.lower()
            data = ''.join([i for i in data if not i.isdigit()])
            data = (data.translate({ord(i): None for i in '][&=%)-@\ufeff;_é$('}))
            char_set = list(set(data))
            vocab_size = len(char_set)
            data_size = len(data)
            char_to_index = { ch:i for i,ch in enumerate(char_set) } # to index each char in d
            index_to_char = { i:ch for i,ch in enumerate(char_set) } # to print generated char
```

```
    return data, vocab_size, char_to_index,index_to_char
```

1 Trump Speech

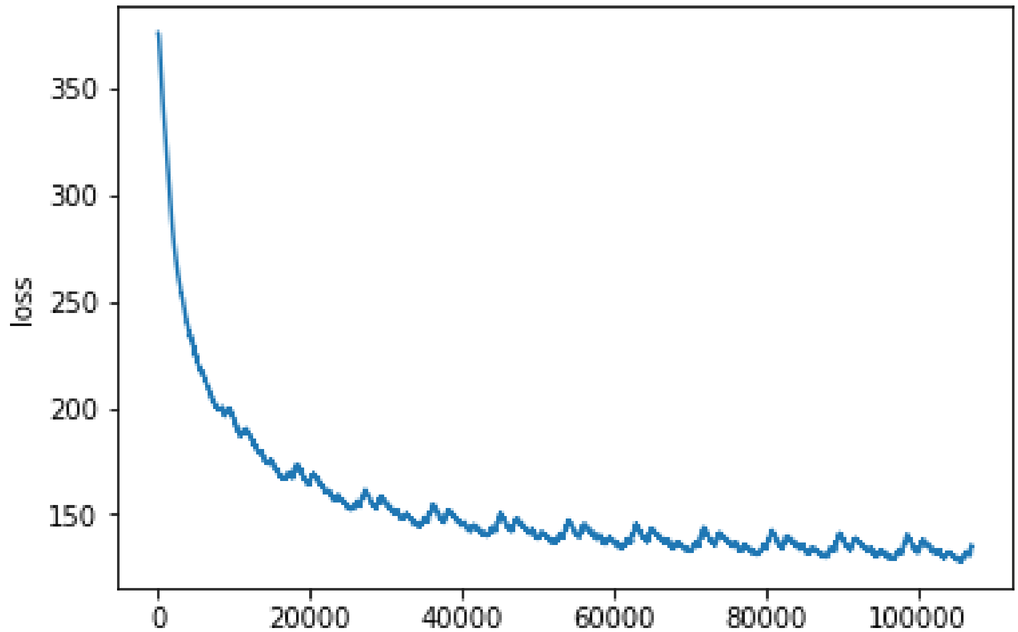
```
In [0]: data, vocab_size, char_to_index, index_to_char = data_preprocess("/content/drive/My Dri
```

```
In [0]: # hyperparameters (chosen by experiments)
        num_hiddens = 150
        batch_size = 100
        learning_rate = 0.001
        num_epoch = 12
```

```
In [13]: parameters, h_init, loss_history = train(data,num_hiddens, vocab_size, batch_size, lea
```

```
Epoch: 1          Batch: 100/891479          Loss: 376.1199891113728
Epoch: 2          Batch: 891400/891479          Loss: 198.5989692792207
Epoch: 3          Batch: 891400/891479          Loss: 170.3894478995746
Epoch: 4          Batch: 891400/891479          Loss: 157.60121457779493
Epoch: 5          Batch: 891400/891479          Loss: 150.44044000065216
Epoch: 6          Batch: 891400/891479          Loss: 145.9852464188745
Epoch: 7          Batch: 891400/891479          Loss: 142.9700438330822
Epoch: 8          Batch: 891400/891479          Loss: 140.81607290079847
Epoch: 9          Batch: 891400/891479          Loss: 139.1327426461128
Epoch: 10          Batch: 891400/891479          Loss: 137.84397843322512
Epoch: 11          Batch: 891400/891479          Loss: 136.83862173950166
Epoch: 12          Batch: 891400/891479          Loss: 135.84353882700896
Epoch: 13          Batch: 891400/891479          Loss: 134.9228162700672
```

```
In [14]: import matplotlib.pyplot as plt
         plt.plot(loss_history)
         plt.ylabel('loss')
         plt.show()
```




```
In [15]: print("Generated text: ",sampling(parameters, h_init, 1000, index_to_char))

Generated text:  . we have great for somethrust hape. and i have a creatia.
whor time for it would we're go to believe than shoull country. it justll so says write trade t

or is talk her. our has politics ire pubying richast is. i seen jobly an of the hightate vely t
so that to bumppriat? but he negertor it will heve  in it was till them. so she ampisiciate for
```

2 Shakespeare Sonnets

```
In [0]: data, vocab_size, char_to_index, index_to_char = data_preprocess("/content/drive/My Dri

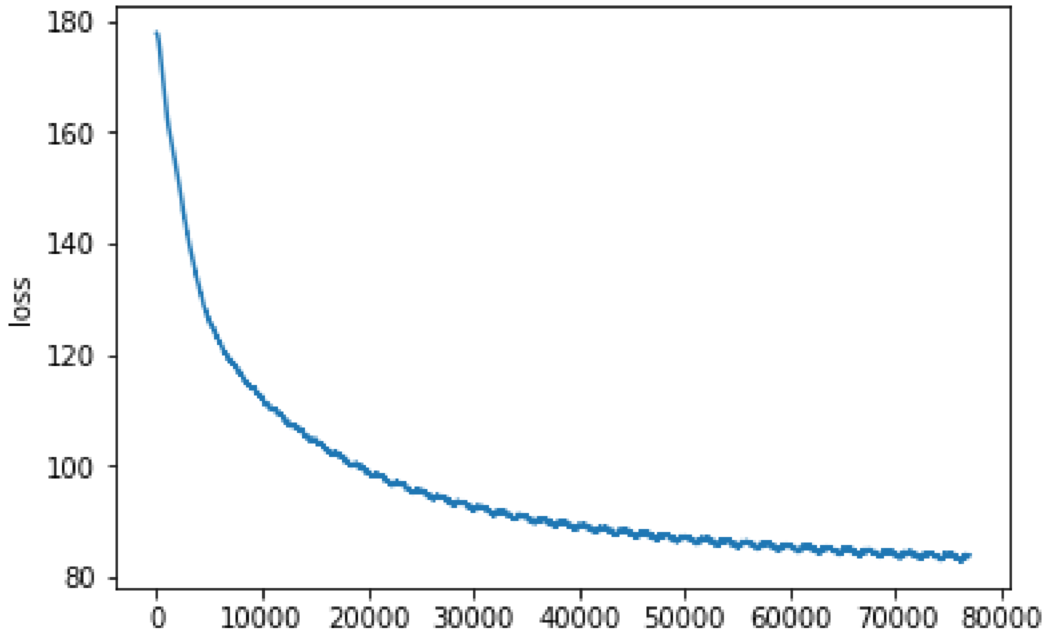
In [0]: # hyperparameters (chosen by experiments)
        num_hiddens = 75
        batch_size = 50
        learning_rate = 0.001
        num_epoch = 40

In [30]: parameters, h_init, loss_history = train(data,num_hiddens, vocab_size, batch_size, lea

Epoch: 1         Batch: 50/96141         Loss: 177.76740676292425
Epoch: 2         Batch: 96100/96141         Loss: 152.87332345994457
Epoch: 3         Batch: 96100/96141         Loss: 133.48517373835352
Epoch: 4         Batch: 96100/96141         Loss: 122.98104313356272
```

```
Epoch: 5         Batch: 96100/96141         Loss: 117.2566426211953
Epoch: 6         Batch: 96100/96141         Loss: 112.97279295517684
Epoch: 7         Batch: 96100/96141         Loss: 109.52457368012955
Epoch: 8         Batch: 96100/96141         Loss: 106.63987367592102
Epoch: 9         Batch: 96100/96141         Loss: 104.12809151900247
Epoch: 10         Batch: 96100/96141         Loss: 101.93276277396208
Epoch: 11         Batch: 96100/96141         Loss: 99.99024230016366
Epoch: 12         Batch: 96100/96141         Loss: 98.30579146634021
Epoch: 13         Batch: 96100/96141         Loss: 96.85819599826198
Epoch: 14         Batch: 96100/96141         Loss: 95.60277932213847
Epoch: 15         Batch: 96100/96141         Loss: 94.4982531963851
Epoch: 16         Batch: 96100/96141         Loss: 93.51305087532857
Epoch: 17         Batch: 96100/96141         Loss: 92.62718008772738
Epoch: 18         Batch: 96100/96141         Loss: 91.82938195606005
Epoch: 19         Batch: 96100/96141         Loss: 91.11222545893507
Epoch: 20         Batch: 96100/96141         Loss: 90.46793798439523
Epoch: 21         Batch: 96100/96141         Loss: 89.88722931454213
Epoch: 22         Batch: 96100/96141         Loss: 89.36083794675807
Epoch: 23         Batch: 96100/96141         Loss: 88.88049029211619
Epoch: 24         Batch: 96100/96141         Loss: 88.43936330917548
Epoch: 25         Batch: 96100/96141         Loss: 88.03292520142264
Epoch: 26         Batch: 96100/96141         Loss: 87.65776193851777
Epoch: 27         Batch: 96100/96141         Loss: 87.30961738176757
Epoch: 28         Batch: 96100/96141         Loss: 86.98376729332455
Epoch: 29         Batch: 96100/96141         Loss: 86.675704684499
Epoch: 30         Batch: 96100/96141         Loss: 86.38220440881477
Epoch: 31         Batch: 96100/96141         Loss: 86.1021769578767
Epoch: 32         Batch: 96100/96141         Loss: 85.83527253864459
Epoch: 33         Batch: 96100/96141         Loss: 85.58124590625765
Epoch: 34         Batch: 96100/96141         Loss: 85.33962784585829
Epoch: 35         Batch: 96100/96141         Loss: 85.10998066427449
Epoch: 36         Batch: 96100/96141         Loss: 84.89229702799874
Epoch: 37         Batch: 96100/96141         Loss: 84.68656177978453
Epoch: 38         Batch: 96100/96141         Loss: 84.49256842112965
Epoch: 39         Batch: 96100/96141         Loss: 84.30754739935313
Epoch: 40         Batch: 96100/96141         Loss: 84.12963874704366
Epoch: 41         Batch: 96100/96141         Loss: 83.95895816560346
```

In [31]:
```
plt.plot(loss_history)
plt.ylabel('loss')
plt.show()
```




```
In [32]: print("Generated text:")
         print(sampling(parameters, h_init, 500, index_to_char))
```

```
Generated text:
ils
know chald mine eye
that cal the time alose.


whose if that verile i do my that shaus: ill.
thy one'd fyemer.
tin have and my bedvegh with the sub'd privaging flomerst where
from thou the trows and i new liother thou roslive might praies if my own now livest deprace,
no leve enerpur do ith'd' faite the prause, breage?
on the crecount,
who, what the bailing drane to pearifed's soof, the weatire
for preasorn that my seeatume,
the eols the getuld thou west to whill when blace,
by serle the wil
```