### 4 Implement a RNN

#### (a) (i) Backpropagation Through Time:

Let the equation for the activation at time step t in the hidden layer be denoted by ht and the equation for the output layer in the forward propagation step be denoted by yt with with three sets of weights

Wxh (weight from input to hiden layer)

Whh (recurrent connection to the hidden layer) and

Who (weight from hidden layer to output layer)

can be written as follows:

With tanh units for the hidden layer, ht can be represented as

**ht=tanh(Whhht-1 + Wxhht)**

With softmax units for the output layer, yt can be represented as

**yt=softmax(Whoht)**

Where softmax is an activation function which calculates the ratio of exponential (e-power) of the given input value to the sum of exponential values of all the values in the inputs and can be represented as 𝛔(z)j

Where,

https://lh5.googleusercontent.com/eSRvTb_N13uaTP6vvt847oD1Wng0G6W8_vj4Ws55DiYF2U6_JKnLcgKVZxTnR93lpyeRgwe6lBEVou2en5evwBXivmpAi-_GbHFOsYP8VzMTIByQhYIDjmwfC5LZFvVdehFyEu-T

#### 4(a) (ii)https://lh6.googleusercontent.com/0jLCPfdbNVv36SUhTJTjiZzlZCKf4Mmk_8pobSjX9tmNS5ERDs11Ab1i9g8CASk47GPQUpjnWmWeaWEyvtq05F_vt1KrhMTJ1l5kC8x49WOxowEpMPeclzicTnYI8DMfiaCKmHDjhttps://lh3.googleusercontent.com/ULQc5GahYsAvbTDV0lOMtX6MVxAkquEqpy_pMOmqy6qaAbQ_y1B8qy3kR38gZwm2GdIEkZoYNXq6vWRllgEsCXohSiGYUgVX51GMJCwQXre3FMxY4-9ggN7J-hOWT-w24wUV9g8n

##### 4 a References:

<https://www.analyticsvidhya.com/blog/2017/12/introduction-to-recurrent-neural-networks/>

<https://www.cs.toronto.edu/~urtasun/courses/CSC411/10_nn1.pdf>

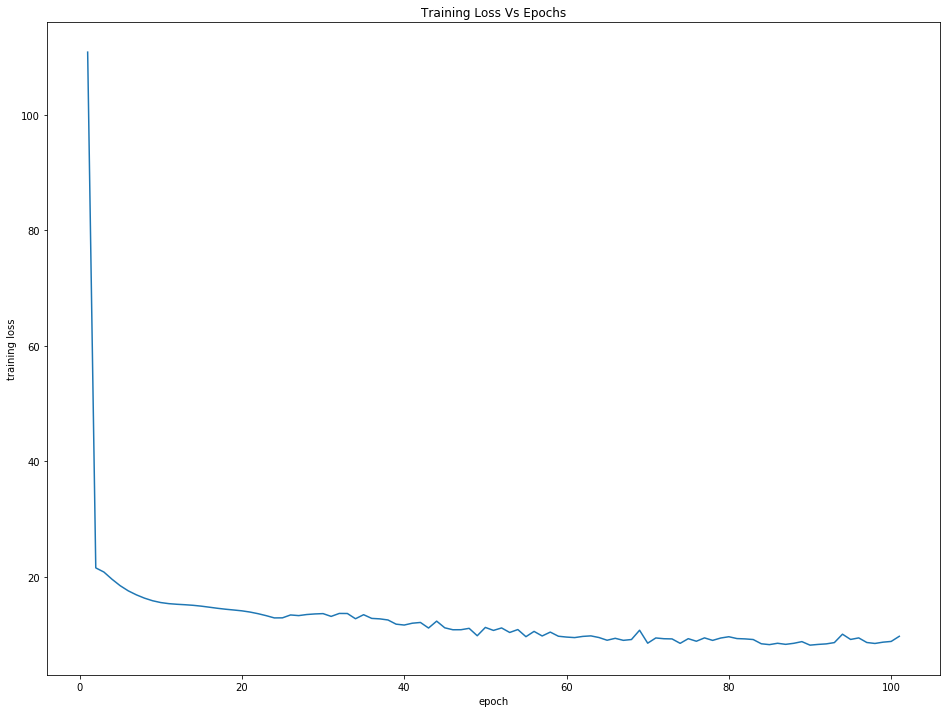
<http://www.philbrierley.com/main.html?code/bpproof.html&code/codeleft.html>

### 4 (b) (i) Training Procedure

For Temperature:1

Hidden units:300

Sequence Length:20



Plot: Training Loss Vs Epochs

For Temperature:1

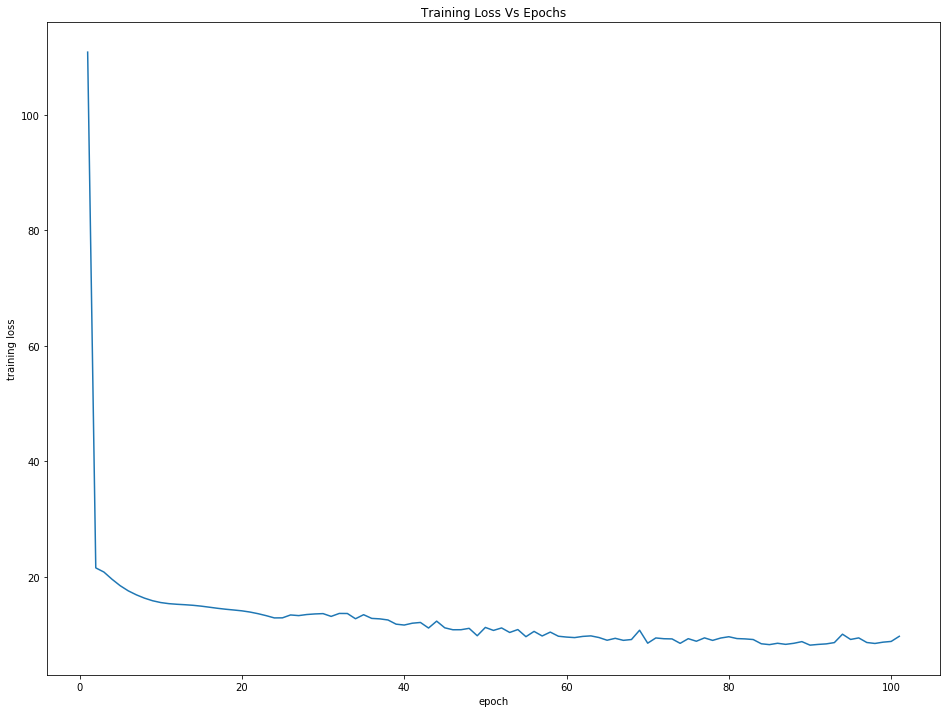
Hidden units:300

Sequence Length:20

The training Loss drastically decreases as the epochs increases leading to efficient training of the network.

### 4 (b) (ii) Breaking Points (20, 40, 60, 80, 100)

After feeding a chunk of training data, the network learning efficiency increases as the epochs reckon to 100 and the loss decreases



Plot: Training Loss Vs Epochs

For Temperature:1

Hidden units:300

Sequence Length:20

Learning Progress by Breakpoints set at epoch intervals of 20, 40, 60, 80, 100 documented as follows:

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#### At Break Point 40

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#### At Break Point 60

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#### At Break Point 80

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#### At Break Point 100

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### 4 (b) (iii) Learning Progress at Breaking Points (20, 40, 60, 80, 100) at different Temperatures (3, 12, 25)

#### **Temperature 3**

##### At Break Point 20

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##### At Break Point 40

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##### At Break Point 60

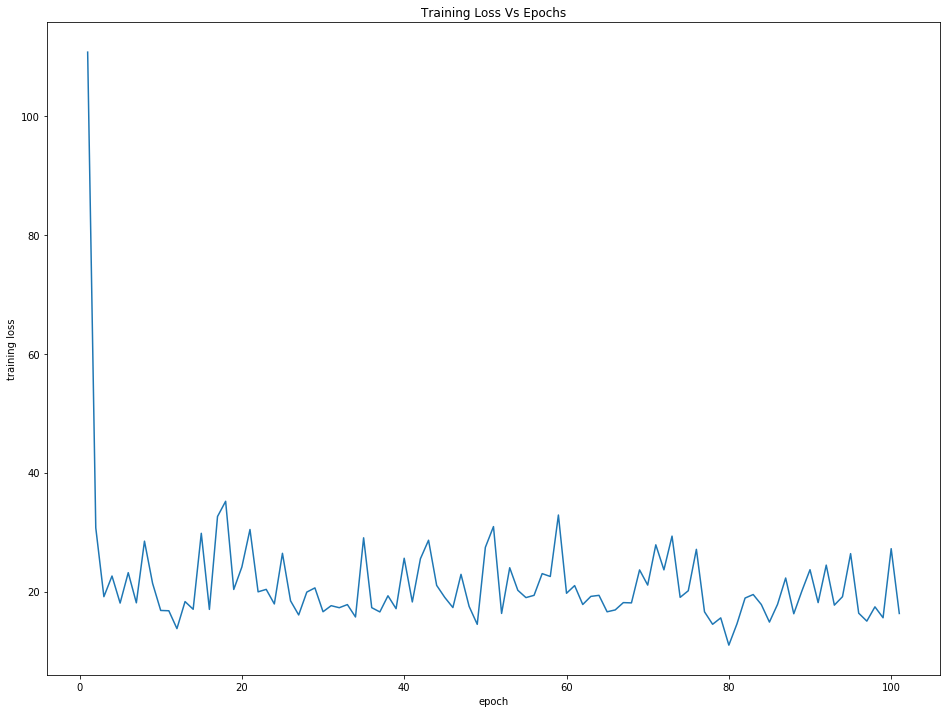
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##### At Break Point 80

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##### At Break Point 100

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Plot: For Temperature:3

Hidden units:300

Sequence Length:20

#### **Temperature 12**

##### At Break Point 20

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##### At Break Point 40



(screenshot from ipynb notebook as the text pasted here is occupying one page per character)

##### At Break Point 60

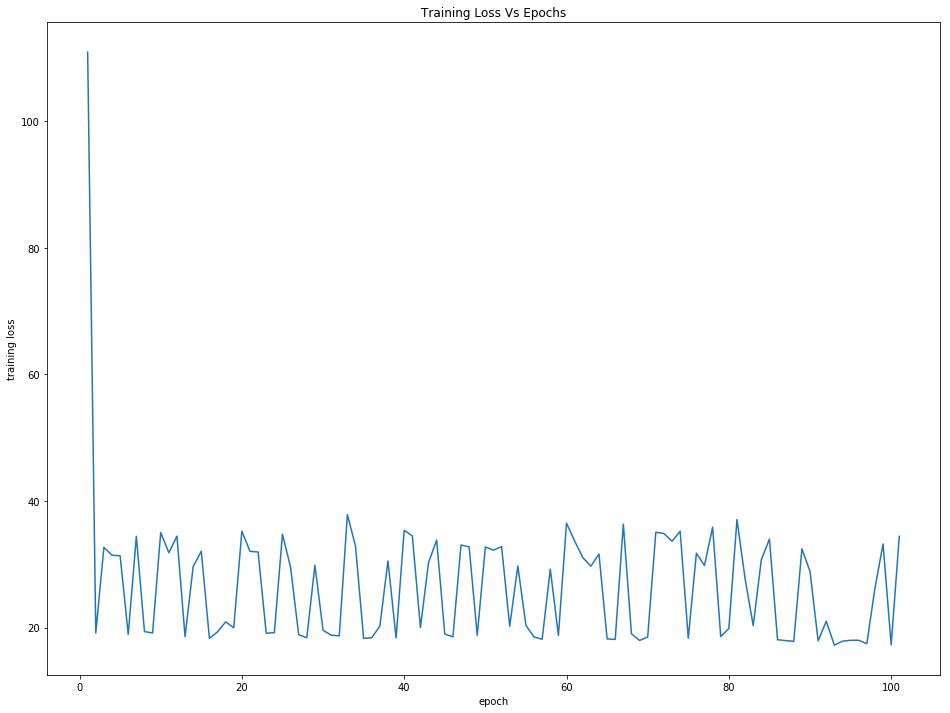
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##### At Break Point 80

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##### At Break Point 100

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Plot: For Temperature:12

Hidden units:300

Sequence Length:20

#### **Temperature 25**

##### At Break Point 20

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##### At Break Point 40

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##### At Break Point 60

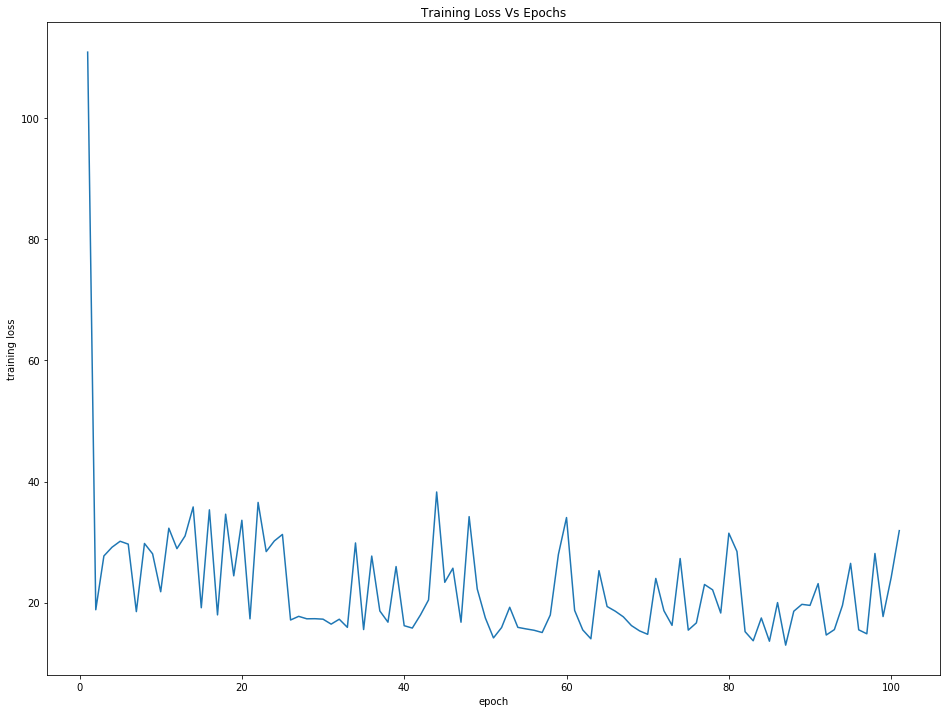
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##### At Break Point 80

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##### At Break Point 100

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Plot: For Temperature:25

Hidden units:300

Sequence Length:20

#### Observations:

For Higher temperatures the randomness of the output sequence is expected and hence it is obvious from the results. We notice that higher temperature T=25, the predicted sequence has more random character sequences but for lower temperature T =3 as the epochs increases the learning gets efficient.

### 4 (c) (i) Number of Hidden Units

#### **Doubling the Number of Hidden units**

For Temperature:5

Hidden units:600

Sequence Length:20

##### At Break Point 20

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##### At Break Point 40

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##### At Break Point 60

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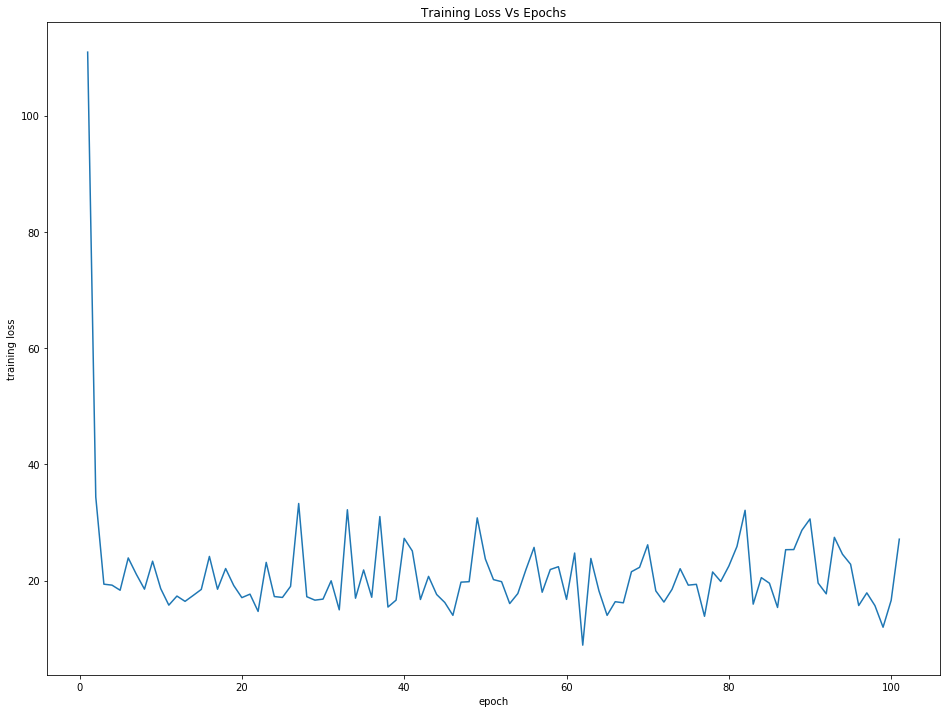
##### At Break Point 80

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##### At Break Point 100

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Plot: Doubling No. of Hidden Dimensions, H=600

For Temperature:5

Hidden units:600

Sequence Length:20

#### **Halving the Number of Hidden units**

For Temperature:5

Hidden units:150

Sequence Length:20

##### At Break Point 20

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##### At Break Point 40

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##### At Break Point 60

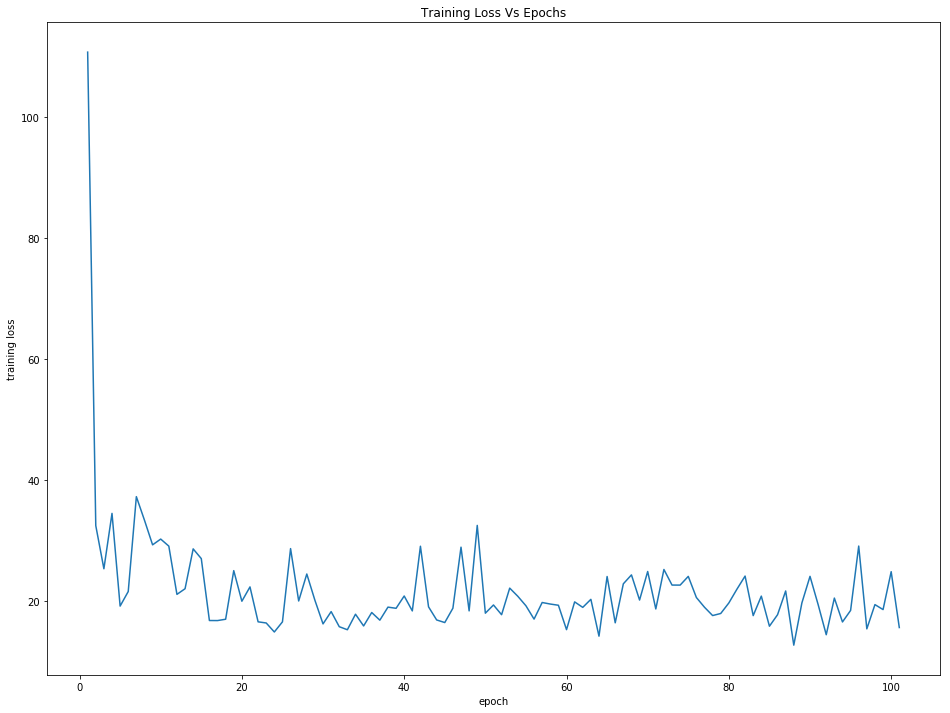
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##### At Break Point 80

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##### At Break Point 100

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Plot: Halving No. of Hidden Dimensions, H=150

For Temperature:5

Hidden units:150

Sequence Length:20

#### Observations:

As the Number of Hidden Units in the Hidden layer are increased, the training time increased .

it is also observed that the training loss is comparatively higher than when the hidden units are halved.

With the Hidden Units halved, the training time is faster.

And also the training loss is lower compared to the hidden units are doubled.

### 4 (c) (ii) Sequence Length

#### **Doubling Sequence Length: 40**

For Temperature:5

Hidden units:300

Sequence Length:40

##### At Break Point 20

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##### At Break Point 40

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##### At Break Point 60

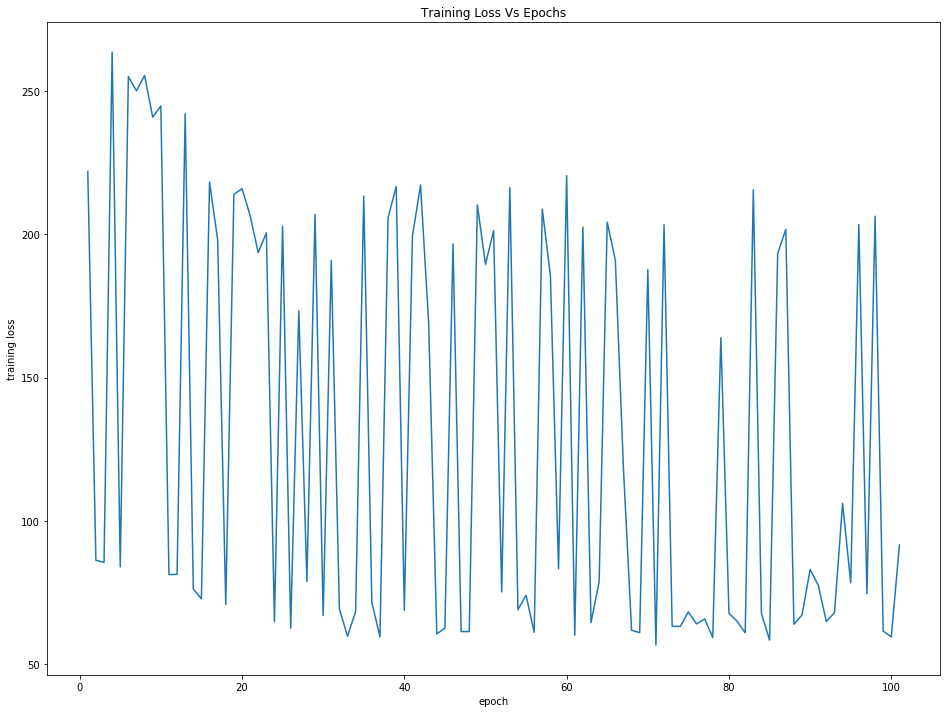
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##### At Break Point 80

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##### At Break Point 100

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Plot: Doubling Sequence Length, Seq Len = 40

For Temperature:5

Hidden units:300

Sequence Length:40

#### **Halving the Sequence Length: 10**

For Temperature:5

Hidden units:300

Sequence Length:10

##### At Break Point 20



##### At Break Point 40

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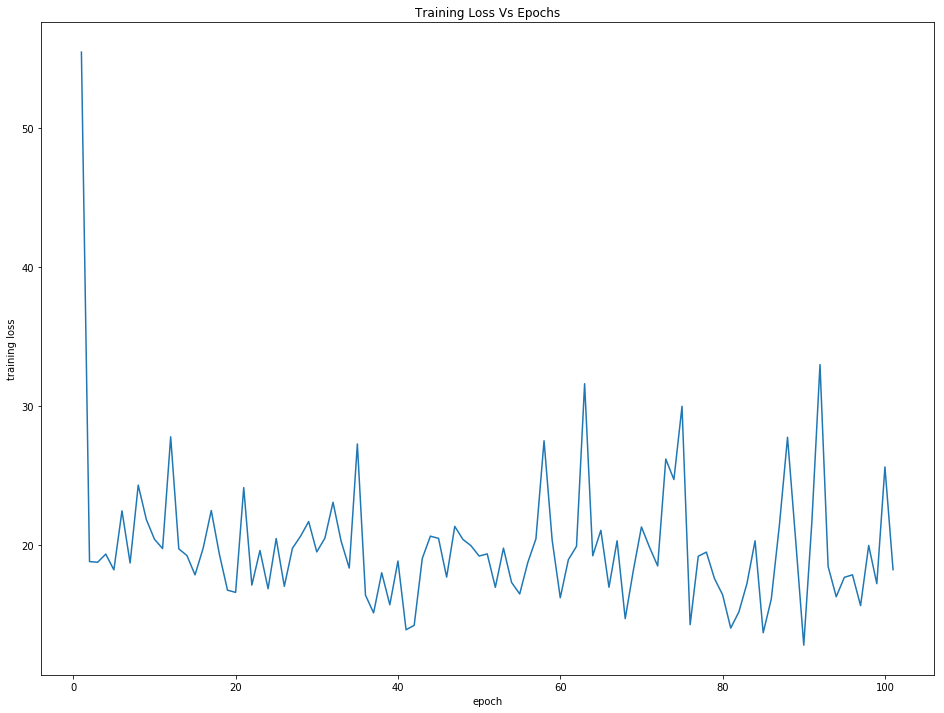
##### At Break Point 60

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##### At Break Point 80

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##### At Break Point 100

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Plot: For Halving the Sequence Length, Seq Len=10

For Temperature:5

Hidden units:300

Sequence Length:10

#### Observations:

When the sequence length is doubled to 40 characters the training loss is much higher and when the sequence length is halved to 10 characters the training loss is significantly lower. There is no significant improvement in the run times as both are noticed to be same. It is observed that with smaller sequence length the training goes well with high accuracy and less loss.