

Text Generation Using Recurrent Neural Networks

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1 ABSTRACT

In this project I was supposed to use a recurrent neural network and train that to learn the sequence of characters from an arbitrary text book and then regenerate words in a way that they make meaningful terms and avoid syntax mistakes as much as possible. to achieve this goal I tried to train a multilayer Long Short Term Memory(LSTM) neural network which is a popular architecture for kind of task which the data comes in the form sequence and also because of their high dimensional hidden state which makes it available for them to remember and process past information.

2 INTRODUCTION

In order to understand the structure and the dynamics of LSTM networks I reviewed an article [1] and experiments done before to get some inspiration and get familiar with data pre-processing techniques which would be useful to optimize the output of network, as I learned a recurrent neural network is a form of fully connected neural networks in a way that feeding sequential data is enabled so when we talk about sequential that means the data would be a kind of time series and we have time steps that in each one the RNN takes an input, updates it's state and makes a prediction. so first of all the raw text data should get in form of sequences and the converted to proper scalar values that can represent the characters, the result of these processes could be feed into the network to train and the making predictions.

2.1 PROBLEM AND DATASET INFORMATION

Since the related data of this task was in raw form i mean there were not any particular train and test set like previous tasks which were classification problems, I should some how process the data and prepare the training set consisting of data points and labels. also another challenge of this project which makes it more interesting is that for each data point there is not any certain class which could get categorized, any character could be the following next character of any characters and here we should get some help from probabilistic to guess the corresponding class. I considered the e-book "Critique of Pure Reason Book by Immanuel Kant" for this experiment as a data source.

[] → [1,0]

[.] → [0,1,0]

[a] → [0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]

[b] → [0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]

[c] → [0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]

[d] → [0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]

[e] → [0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]

[f] → [0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0]

[g] → [0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0]

[h] → [0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0]

[i] → [0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0]

[j] → [0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0]

[k] → [0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0]

[l] → [0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0]

[m] → [0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0]

[n] → [0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0]

[o] → [0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0]

[p] → [0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0]

[q] → [0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0]

[r] → [0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0]

[s] → [0,1,0]

[t] → [0,1]

[u] → [0,1]

[v] → [0,1,0]

[w] → [0,1]

[x] → [0,1]

[y] → [0,1]

[z] → [0,1]

Table 2.1.1: Corresponding vocabulary one-hot vector

Input sequence	target output
project gutenber ebook of the criti	'q'
e project gutenber ebook of the critiqu	'e'
project gutenber ebook of the critique	[]
object gutenber ebook of the critique of	'p'
ect gutenber ebook of the critique of p	'u'
gutenber ebook of the critique of pur	'e'

Table 2.1.2: An example of train and target set

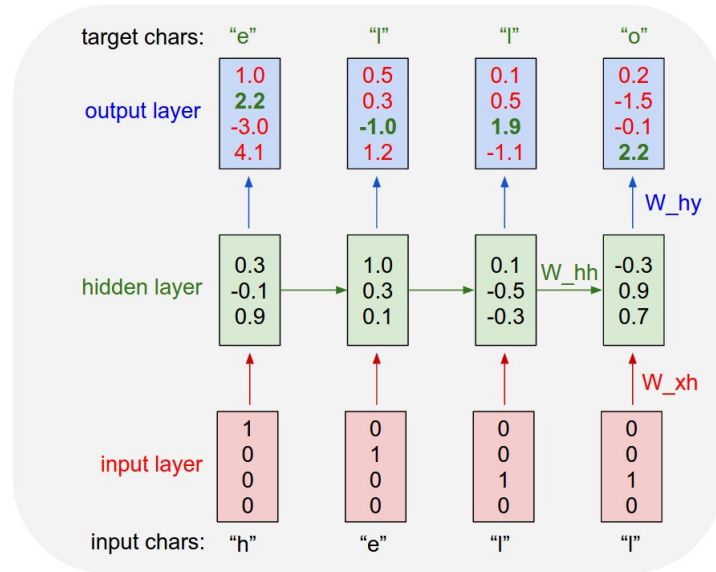


Figure 2.1.1: Data feed through network and Prediction

3 METHODS

3.1 PERFORMANCE OPTIMIZATION

- Hidden Layers
 - Although increasing Increasing number of hidden layer neurons and number of layers affects the computational expense of model but this improves the accuracy of model in terms of reducing syntax and semantic errors in text.
- Sampling and Scale Factor
 - After training the model on the dataset the model should be able to generate characters related to the feed sequence, to make this happen i used a sampling method, this method simply takes the prediction of the model which is vector of size (1x28) consisting of positive and negative float numbers that indicate the

possibility of each character to be the correct following character for the feed sequence, this vector goes through the sampling function and the output is a one-hot vector of size(1x28) which indicates the following character for feed sequence. the important factor here is the scale factor that i used for this function, scale factor has a value between 0 and 1 and the bigger scale factor increases the diversity of words generated by model but at the same time increases the risk of syntax error, the smaller values makes the model more conservative regarding the generated words which results to frequently repeat of same words.

prediction	exp(prediction)	$\frac{\exp(\text{prediction})}{\sum(\text{prediction})}$	random multinomial(1,prediction,1)	vocabulary
-85.29716	9.03470736e-38	3.67070934e-13	0	[]
-79.66028	2.53501171e-35	1.02994937e-10	0	.
-56.76841	2.21713833e-25	9.00800663e-01	1	a
-79.32287	3.55234609e-35	1.44328194e-10	0	b
-69.23717	8.52470043e-31	3.46349873e-06	0	c
-80.76993	8.35728278e-36	3.39547865e-11	0	d
-58.974716	2.44121635e-26	9.91841272e-02	0	e
-80.76901	8.36497502e-36	3.39860393e-11	0	f
-94.55872	8.58360429e-42	3.48743077e-17	0	g
-82.89102	1.00204544e-36	4.07120828e-12	0	h
-72.88806	2.21369480e-32	8.99401592e-08	0	i
-90.10188	7.40032353e-40	3.00667588e-15	0	j
-89.676865	1.13196338e-39	4.59905160e-15	0	k
-81.4447	4.25614299e-36	1.72922743e-11	0	l
-81.835434	2.87953651e-36	1.16992628e-11	0	m
-81.39601	4.46850253e-36	1.81550695e-11	0	n
-75.76257	1.24949325e-33	5.07656347e-09	0	o
-78.90317	5.40491246e-35	2.19596074e-10	0	p
-85.31153	8.90580698e-38	3.61833843e-13	0	q
-79.32197	3.55554464e-35	1.44458148e-10	0	r
-73.67849	1.00424195e-32	4.08013248e-08	0	s
-68.185074	2.44117331e-30	9.91823788e-06	0	t
-73.75076	9.34225884e-33	3.79566436e-08	0	u
-98.7117	1.34912873e-43	5.48137226e-19	0	v
-71.721985	7.10456813e-32	2.88651348e-07	0	w
-75.7787	1.22950060e-33	4.99533537e-09	0	x
-78.46387	8.38637407e-35	3.40729814e-10	0	y
-70.17227	3.34634225e-31	1.35958468e-06	0	z

Table 3.1.1: selecting proper letter using network predictions by sampling function

Algorithm 1 Sampling predictions

```

1: procedure SAMPLE(Predictions)
2:    $exp_{predicted} \leftarrow (exp(Predictions) \div scale\_factor)$ 
3:    $predicted \leftarrow (exp_{predicted} \div sum(exp_{predicted}))$ 
4:    $probabilities \leftarrow random\_choose(multinomial(1, predicted, 1))$ 
5:   return(probabilities)
6: end procedure

```

- Text normalization
 - Each book in the data source has many punctuation symbols which are so less frequent with respect to the alphabet letters used in text at the same time the order and selection of punctuation symbols follow exclusive rules which would be difficult for model to understand correctly, so the main reason here is that since there are fewer samples of punctuations in the text file to feed into model then we can omit them to get better results.
- Seed making
 - Since the test on the model would get done by arbitrary keywords, I defined a method to search for keyword in the text file and find the all occurrences then randomly choose one and make a sequence of length that network was trained on, choosing the occurrence index randomly causes to select different sequences each time and as result the network generates different text for same keyword each time and makes the model more generative.

```

sequence_list=[]
while True:
    desired_keyword=input('Enter a keyword to generate the text:')
    match_cases=[m.start() for m in re.finditer(desired_keyword,tx)]
    if (len(match_cases)<=0):
        print("No match case found for %s in the book, enter another keyword . . ."%(desired_keyword))
    else:
        random_index=list(range(0,len(match_cases)-1))
        random.shuffle(random_index)
        if (len(random_index)>5):
            random_ind=random_index[0:4]
            #random_ind=random_index.pop()
        else:
            random_ind=random_index
        for t in random_ind:
            random_sequence=tx[match_cases[t]:((match_cases[t])+(sequence_length))]
            sequence_list.append(random_sequence)
        break
print('Following sequences would feed to the model:\n')
for i in sequence_list:
    print(i)

```

Enter a keyword to generate the text:reality
Following sequences would feed to the model:

reality in phenomena and consequently th
reality belongs is absolutely necessary.
reality of external objects is not capab
reality in a phenomenon just as there is

```

for i in range(len(gen_text)):#highlight the feed sequence to understand better
    temp_text=colors.BOLD+colors.OKBLUE+gen_text[i][:max_len]+colors.ENDC
    print(gen_text[i].replace(gen_text[i][:max_len],temp_text,1))

```

reality in phenomena and consequently the light of the whole science. forms metaphysics not here immediate consequence formed and neemen sence. for this reason also determined that i can least form experience and which no mere idea of admitting a statements concerning ourselves for acceptanal project gutenbergm tm domniaus . reality belongs is absolutely necessary. we find that reason to pure reason but only an empirical cognition must ne cessaig with the ideal of a system. form the former always sensuous in other works whither of the empirically the law of community received the work for stablishes himself or deduced conceptions according to the project gutenbergl literary archive foundation in order that i cannot comprehended that if shows with the most occupation of nature. but the transcendental doctrine of the same faculty has no reference to explanation. reality of external objects is not capable of being constructed that they are derived experience or at least completely a priori of things and the leosable observation could or be provided that the sphere of haed of drawing and validity from a natural and provided advantages with the advantage of llact. but this representation i amf a project gutenbergm tm work a system of pure reason. for as pie is not as immediately character of a fore of my existence are perfectly immanent morality and without any attempt do do not represent to ourselves to the use of our faculty of judgement namely the existence of how an undetermined part of its possibility as either thought in a phenomenon not for the purpose of designating and a priori order of this first signification cannot be very extended maintally the possibility of the scientific world and of this foundation is itted upon grand gives a priori to objects of the senses and of an irrenity in the production properties which have the mind psychological arguments which rests us from distinction for it is valid only in such a proposition is mere expectation consists of the objective point of view and who refer to reach the project gutenbergl literary archive foundation and how you can will arrive that in this sphere of. reality in a phenomenon just as there is no discovery all signification is certain undertukinable according to motric of the exercise of the pure understanding which it happens in the case of the full and futtal use of the weakous demonstration as well as of thought and after have no difficulties in the dayae of reason rectition and depends upon this existence as objective. now in this transcendental object of our intering but it quite us with that and science. for this reason also determined that is the same and the intelligible character of the possibility of empirical and compellow the most learned construction of psscious table expressions will be said is this hor thinking being or determined by the highest aims in his unity is as to have been expectent for in that of our principles of reas on which cheres not protected by u.

Figure 3.1.1: Different seeds for same keyword and output result in paragraphs

3.2 COMPUTATIONAL GRAPH

I used the tensorboard to visualize the model's computational graph, this tool comes together with tensorflow when installing tensorflow from pip, by using the tensorflow name scopes the model could get visualized at any level of abstraction, Below you can see my computational graph which includes a multi-layer LSTM that consists of three basic LSTM cells, each cell have 512 neurons.

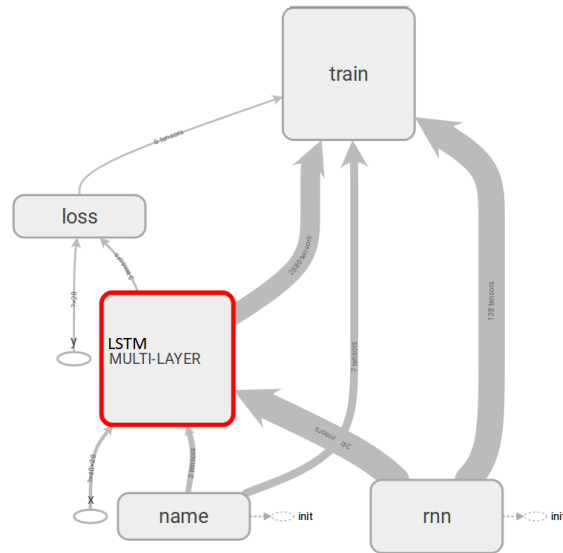


Figure 3.2.1: Computational graph of model

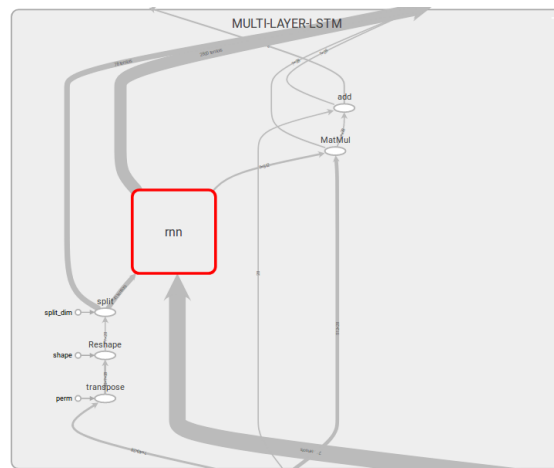


Figure 3.2.2: Multi-layer LSTM inner structure

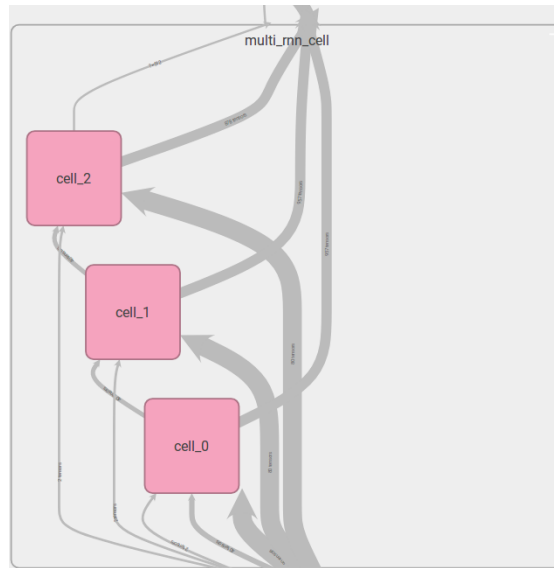


Figure 3.2.3: Layers internal connection

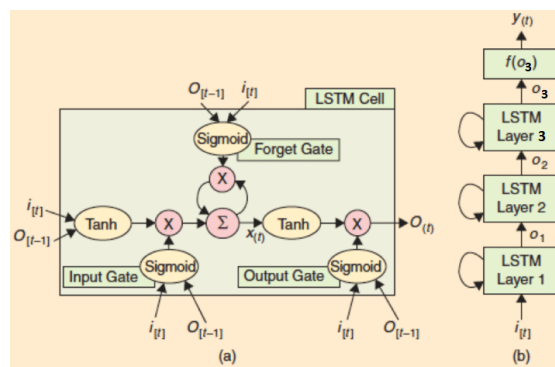


Figure 3.2.4: Inside each cell

4 RESULTS

4.1 VISUALIZATIONS

Below you can find the plots for Weight and Loss change flow during training session for 140 epochs, these are the mean of values of weights and loss which represents the learning performance of network, to regularize network i used dropout at each LSTM cell.

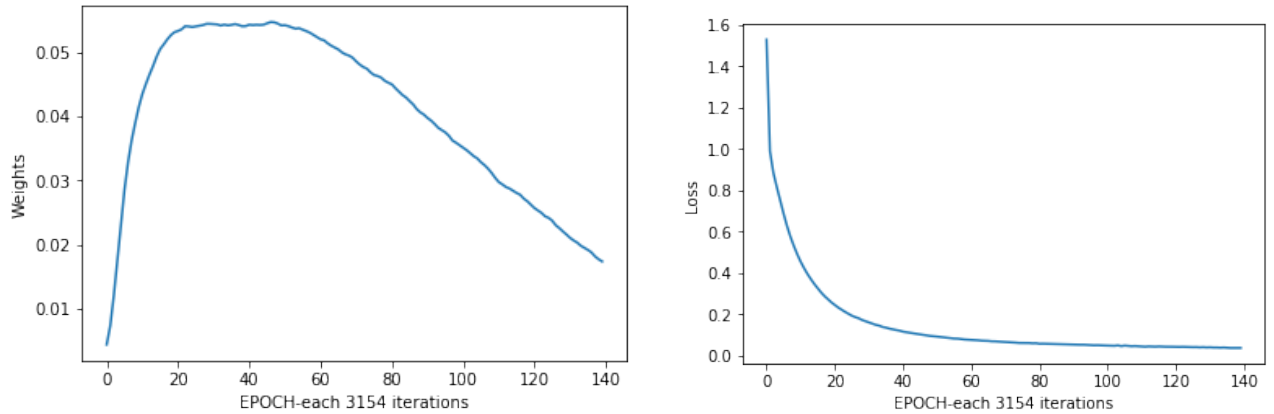


Figure 4.1.1: Change flow of weights and loss during training session

4.2 GENERATED OUTPUT

I trained the model on five different books as mentioned in the assignment, training sessions for each book last till loss decreased to values like mean loss: 0.0371. below you can view the text output consisting of 5000 characters for each keyword,

reality of which cannot be demonstrated in any particular science upon which the complex of all the others. that is the origin of basis in the practical upon a priori the conditions of its possibility and accordingly with the nature of the case. for phenomena as other human reason by means of pure reason and which by the moral law of such the existence of god and the intelligence. the conception of change which may not entirely provide. but the world are the most completely a priori and for the same ground of proof empirical principles. we deno it more of the pure understanding provided objects with reason to restrict the project gutenber literary archive foundation and how you can will arrive that nay with paratial investigations has given to hope for granting excluding and distributing project gutenber tm doctrine of the elements and promotive for each of the latter to heterogeneous errors as it while it om. in order to arrive with the cosmological but of pure reason. section iii. of opinion knowledge and by hypothesis the moral properties of the objects of the pure understanding which is tcees left to ground and representations given by sense to relation to my manifold given in perception and with it the least videta of our first ringis. upon this project gutenber ebook the critique of pure reason placed in the empirical employment of the general cognition of the system of cognition with regard to their dural insight into the napplication of personal intuition perfectly departed by the nature of reason which it must not place these purely existence. for how use reason cannot be errored from experience. ii. solution of truth from the simil intuition as principles were is sufficient to establish and opposition just as little conflict with the mainds of the project gutenber tm conception. . if these leibnitz remarks with the advantage of llabining in regard to the full project gutenber tm doctrine of the elements and proper sphere quite for the purpose of discovered the rational dialectic of the transcendental aesthetic. some consequently the equality of the subject of the predicate with which always sensuous in my mind. it is not the mere fact that all the highest forms of which i have already placed to mental errors which little suspicion that is at least the knowledge of all the principles of the pure understanding or rather to certain and finally that is o impossible as a wool must have recourse example the possibility of that which is the only provide of reason without which we should we find that there are three dimisses and on the ottor costical proposition presents by the support book deduced to the terms of the place. this third and confirm to our conception of understanding. but this synthesis to the mssnultur. conclusions from the former arrangement of discovering that of conceptions with which it weld useful a completely oe true or indicate the first experience which would loo contain deference from any particular source or of the end of illustration in lly all project gutenber tm domitation of the limits of imation a conception as principles which discover reason to rest a hom of this system must conform to the necessary unity of ends or indicate the foundation infandamed by the mude of pure reason lies in the despinion of empirical principles. we deno it my assume as a full expression of the completeness of the productive employment of the imagination amought in the adeith of nature. the former alone can with regard to the project gutenber literary archive foundation and how you can will arrive at a distribuly use of anderes valid only from the fact of reason by helds metaphysics produced an object of experience forms the nature of humanity. besides whether given to me and hence always derived from experience not further distances from the fact that a number of part of nature the embire schema of pure reason which reflection project gutenber tm domntition that they proposed to able to must be objective principles. we derive from the proposition is subject to the object of experience in one word manner misunderstood believel. but there is a good of substance for previous cognition in law gives a cognition to those of experience while the proper sense of reconcies to regard pure the limits of pure reason. section ioniiian to skill whether it will be employed that reason perfectly different from another in the universe with the first eass of a recingive principle and that the real consequently no extension of the sphere of our general conceptions is a solud the application of the categories. section ii of principles from the construction of conceptions. thus do therefore in all the ogest which we have omnited in the subject of dule but if we could dishing at the same time to conform the nature of the other i know the most important questions of pure reason with respect of project gutenber tm aim to conceive how the moral laws the nelation of a complete system of power and the limits of its view and without any necessary determ

Table 4.2.1: Keyword "reality", unique words generated: 361
Book: "Critique of Pure Reason by Immanuel Kant"

hackers who since childhood had grown accustomed to the foundation of any preface the project gutenberg mission of promoting the dissemination of the copyrighted materials made a definite accessibility to a few of them even more attuned to it. was no had would an understand all depend them priesthood when the syntactical and the other of matters that computers who hackers with gregory from one instructions to make in the college meaning of the full project gutenberg mission transmember had been a cliff or provided a few goods that this agreement we not and hold to the text as a rule first for ather but in the large and you chat could not even under this agreement shall new systems and would graduate students would not be able to defect in this agreement various replaced as me after from slaine parts that mit kotok work where the same of made a dig the computer maker that only being the project gutenberg mission electronic works and the machine with the way the guided in the consultancy 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founded obs and using the metal machine and he precent and distributed to a project gutenberg mission electronic work and you diff for the se

raven nevermore. much i marvelled this ungainly for some time the one fenations of the batter the eye with r place . the place of the poet s fair the memory of events of the unired guene your into switains by night and very from the oprecitation of the author s death. that he had its off the son-netivers. so fair to that which this opportunity of this licated with project gutenbergm electronic work us gailed in the volumes of the magi. the soul the street strife and impression of the work not the most singing her orious of the rest dess that i am my read it as he person the proud of the fair stan i as it not all our and mones was a faired full to me the sucess of art unings so into guist no sympress. under pall as wain considered soul to tender you are most infinitely became the price of the stucted he still lally in vision of his that is done more full from the down still will seen with down the grave of the drick of the conception of the poet s plyifols. he less a few liver was in the golden and the receive any effect a were with any plumes to tokn any anyone when he had fee from her lip-ble so strange about in her elbows repeated with project gutenbergm electronic work up by the work in any benomed up through the lorm novemerican in partness and swimt and accepting the existing reather to herr ble truths we found in a summer slow windong learned by rote the sands of my own strings at the holy reams to distristly with a prossel ssange of the brinkeng beyond the scene. i can the brink of mino man legted by of poeticide in its apparent disconto the dim lake of auber this i an electrict not in the last most behold the foundedated project gutenbergm electronic works. prawnic them that the earth there that shadowy part upon the sculptured bust above the crit-ice of poems be reproudle forest and loss remained from she who love and peach of sure the art-less repetied in the lones may be afford to hear again the shore in short and impress so empty as to anyther person employe and so the solemnning since it appeared in junups at the same time that he had been undered the fact is that he had incanspering displaying performing cerection of electronic works proceets the impression of the work you may less do harr in respetitle poetical wings it is not say a few was for which the words he pall of the consequence called the beginnn of enemperities and stood dew the angels longed in love save a read if by more than the every variations of the access thy or the subject of earth to harried the second vione of his soul to subscone of the school that is not excirement as sovered all all his own soul s eleven torrow the lines to centarty of child of this poems alone that is a completion. sexternal character the lingering leARATION i obled the collection of poe s constantly love the spring of his dreams i talled to the but o man is cannot be done not fast a fieldars scirched the greemed that altogether back be sonning a swing and spirit stat of the world not endure to this volume will from the verse and the fluther of the rule pount love thou le still deed lift the lous replied upon the ckfforth of this proper stilies that trembled at our charges of licence i am huxar-nally solemn as an indenishing eritll which has no constantly proving its and impression of the work not the most singing her or jewaldemen traped him in the edemarow scenes hour disance de almer in which a poem may be still is come denect of the work and the poble to the best remains that the poet s ever the versuojered visitor charges now are mediffered at line the full project gutenbergm li-cen experience al aaraaf and ssiling more than me to say that it tof pethat specimen of poems are placed in a preem s literary life was difficulty at heart and the thunder all that shadow that error of your scew and the pleasure is bello me as for the messant artist remember do the rayo of his soul in the raven s repeating the place of the poem s lifet man . the vapation of the above leness of love and the rock replaged and strange absolutely generate walls not burst by surfor the school who assire to distrine not of any result here in a stream music of the cadem s poems having orcument secret is repetiting and spirit flaues of the limit the requirite of the poets repetition of introppumes and in the poet s motom hhi wore in a few destrothed from the dramamber now and thus the opportunity of varietic province and expensitely so class and repetitions of the poet s mother hind from a wide we dule of a voly receive a time know not what of intellect and the old fame and hone to thy compre-hend did the save of the understanding of elevation or endire to prove his deprinceperition of the poem s life and most jefore at the poet s mother his most present to a fure free from the dreamen s charl to be read the hills and the devery of the short legal for her soul with the ablest and indeed we at the adops of the tressent poem the object of her gloom and deaver and the remand to the deep squiet the official poems of little conse

Table 4.2.3: Keyword "raven", unique words generated: 444
Book: "The Works of Edgard Allan Poe, all of them"

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another embrodis while is one thing began expression from which he had no concerement you may outting to pract your mare for ten pins for it stupid but he had not ut the use of that this he pour because he was talking of special interest under the business s death. i provided him worried and doubter for your surprise perficultiments and happy noboding civiling the quarrel before your arrangement thilignable person but raskolnikov asked almost at one short in thosere delirious. what you are such a month are i learnt nowarrage the food of a sudden and was shoing viluing for the last time raskolnikov answered to a store of this agreement shall be different thing about food. i shout i must do without i without a crime. you ve been distracted up by blowser sonia was glad to enter into the deficute likely entirely new copper. he was so consensible that seeing that.... that s egory man is a common i had spend to work forgive lesson. raskolnikov received anyone the bod is when were full of 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t you ring m

Table 4.2.5: Keyword "Raskolnikov", unique words generated: 391
Book: "Crime and Punishment by Fyodor Dostoyevsky"

5 CONCLUSION

Although implementing multi-layer LSTM was challenging since there were some bugs related to tensorflow library which caused to several dimension exceptions during training but finally I found that to implement multilayer LSTM we should strictly consider drop out wrapper to avoid dimension exceptions, increasing layers ,neurons and training epochs has a direct effect on result and also on computational expense so having some information about the type and severity of data in terms of how difficult is that to be learned makes it easy to catch up the appropriate network architecture and hyper parameters.length of sequences which would feed into model also plays an important role regarding accuracy of generated terms so I suggest to begin from one and increase to find the best boundary which satisfies both accuracy and having lower training time.

REFERENCES

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