

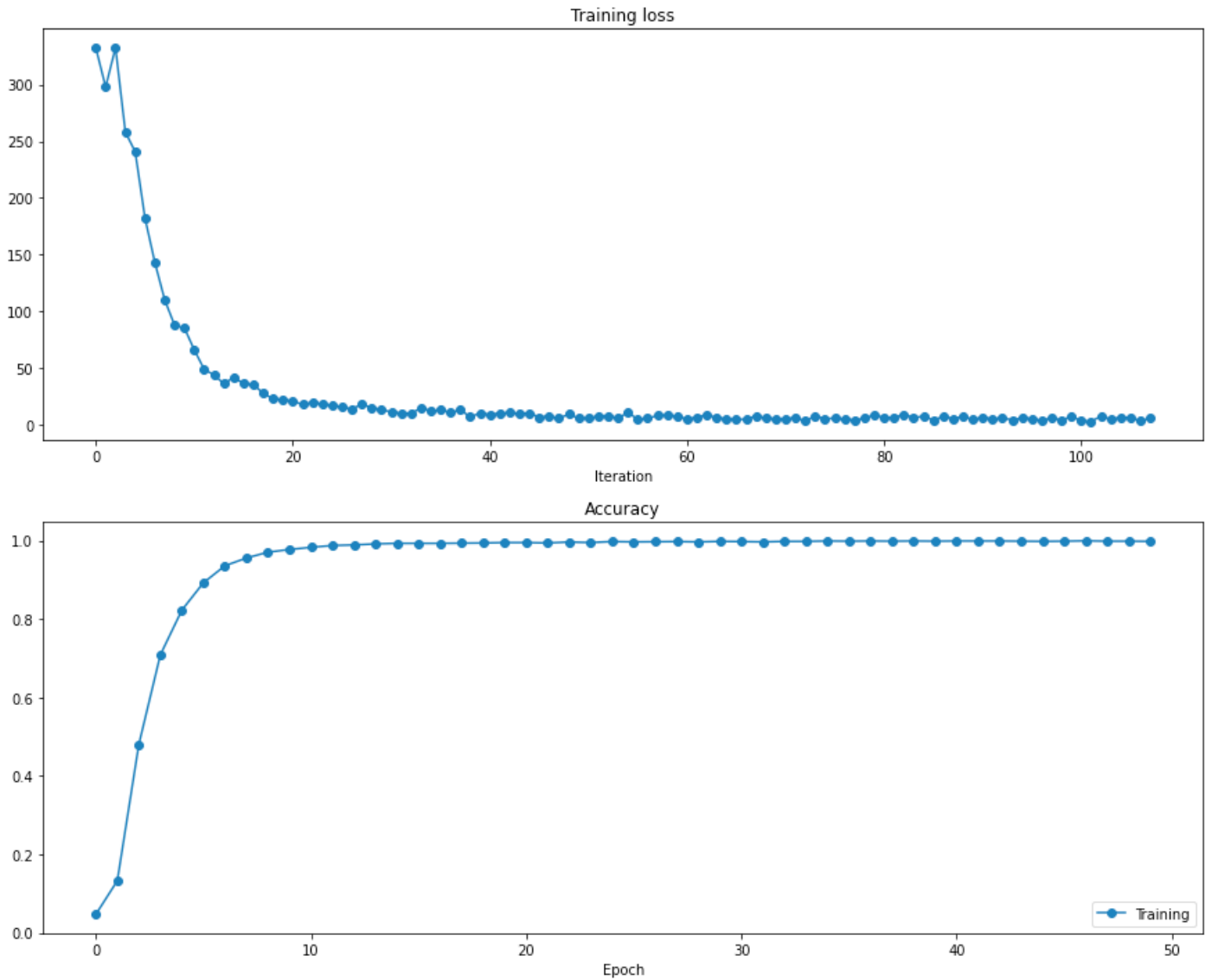
## Programming Assignment #1

## 1. Training loss / accuracy curves for vanilla RNN and LSTM training

## 1.1 Vanilla RNN

```
(Iteration 1 / 10800) loss: 332.80412961176955
best performance 6.639004149377594%
(Epoch 1 / 50) Training Accuracy: 0.06639004149377593
best performance 35.40802213001383%
(Epoch 2 / 50) Training Accuracy: 0.35408022130013833
(Iteration 501 / 10800) loss: 140.20031833528833
best performance 60.7192254495159%
(Epoch 3 / 50) Training Accuracy: 0.607192254495159
best performance 73.72060857538037%
(Epoch 4 / 50) Training Accuracy: 0.7372060857538036
(Iteration 1001 / 10800) loss: 52.68114059246818
best performance 81.05117565698478%
(Epoch 5 / 50) Training Accuracy: 0.8105117565698479
best performance 86.72199170124482%
(Epoch 6 / 50) Training Accuracy: 0.8672199170124482
(Iteration 1501 / 10800) loss: 37.78499743451447
best performance 89.02720147533425%
(Epoch 7 / 50) Training Accuracy: 0.8902720147533425
best performance 90.73305670816045%
(Epoch 8 / 50) Training Accuracy: 0.9073305670816044
best performance 92.9460580912863%
(Epoch 9 / 50) Training Accuracy: 0.9294605809128631
(Iteration 2001 / 10800) loss: 29.161251407406276
best performance 93.59151682803135%
(Epoch 10 / 50) Training Accuracy: 0.9359151682803135
(Epoch 11 / 50) Training Accuracy: 0.9336099585062241
(Iteration 2501 / 10800) loss: 21.554291601289442
best performance 95.4817888427847%
(Epoch 12 / 50) Training Accuracy: 0.954817888427847
best performance 95.8967266021208%
(Epoch 13 / 50) Training Accuracy: 0.958967266021208
(Iteration 3001 / 10800) loss: 16.724900724424543
best performance 96.03503918856616%
(Epoch 14 / 50) Training Accuracy: 0.9603503918856616
best performance 96.91101890272014%
(Epoch 15 / 50) Training Accuracy: 0.9691101890272015
best performance 97.37206085753803%
(Epoch 16 / 50) Training Accuracy: 0.9737206085753803
(Iteration 3501 / 10800) loss: 19.65177648435776
best performance 97.60258183494697%
(Epoch 17 / 50) Training Accuracy: 0.9760258183494698
(Epoch 18 / 50) Training Accuracy: 0.9746426924850161
(Iteration 4001 / 10800) loss: 14.237597156652186
best performance 98.10972798524665%
(Epoch 19 / 50) Training Accuracy: 0.9810972798524665
best performance 98.38635315813738%
(Epoch 20 / 50) Training Accuracy: 0.9838635315813739
(Iteration 4501 / 10800) loss: 13.42541652079034
(Epoch 21 / 50) Training Accuracy: 0.9815583218072844
best performance 98.61687413554634%
(Epoch 22 / 50) Training Accuracy: 0.9861687413554634
(Epoch 23 / 50) Training Accuracy: 0.9861687413554634
(Iteration 5001 / 10800) loss: 8.16380201063142
```

best performance 98.70908252650992%  
(Epoch 24 / 50) Training Accuracy: 0.9870908252650992  
best performance 98.89349930843707%  
(Epoch 25 / 50) Training Accuracy: 0.9889349930843707  
(Iteration 5501 / 10800) loss: 8.11848989414598  
best performance 98.98570769940065%  
(Epoch 26 / 50) Training Accuracy: 0.9898570769940065  
(Epoch 27 / 50) Training Accuracy: 0.9898570769940065  
(Iteration 6001 / 10800) loss: 8.969727638026047  
best performance 99.03181189488244%  
(Epoch 28 / 50) Training Accuracy: 0.9903181189488244  
(Epoch 29 / 50) Training Accuracy: 0.9898570769940065  
best performance 99.07791609036423%  
(Epoch 30 / 50) Training Accuracy: 0.9907791609036423  
(Iteration 6501 / 10800) loss: 9.666497935141336  
(Epoch 31 / 50) Training Accuracy: 0.9907791609036423  
best performance 99.26233287229138%  
(Epoch 32 / 50) Training Accuracy: 0.9926233287229138  
(Iteration 7001 / 10800) loss: 9.591665960232383  
best performance 99.44674965421854%  
(Epoch 33 / 50) Training Accuracy: 0.9944674965421854  
(Epoch 34 / 50) Training Accuracy: 0.9912402028584602  
(Iteration 7501 / 10800) loss: 7.209955452302791  
(Epoch 35 / 50) Training Accuracy: 0.9940064545873675  
best performance 99.5850622406639%  
(Epoch 36 / 50) Training Accuracy: 0.995850622406639  
(Epoch 37 / 50) Training Accuracy: 0.9935454126325496  
(Iteration 8001 / 10800) loss: 7.252622578538748  
(Epoch 38 / 50) Training Accuracy: 0.9944674965421854  
(Epoch 39 / 50) Training Accuracy: 0.995850622406639  
(Iteration 8501 / 10800) loss: 9.027480773761422  
best performance 99.67727063162748%  
(Epoch 40 / 50) Training Accuracy: 0.9967727063162748  
(Epoch 41 / 50) Training Accuracy: 0.9930843706777317  
(Iteration 9001 / 10800) loss: 5.937475618457642  
(Epoch 42 / 50) Training Accuracy: 0.9944674965421854  
(Epoch 43 / 50) Training Accuracy: 0.9953895804518211  
(Iteration 9501 / 10800) loss: 8.966965476723406  
(Epoch 44 / 50) Training Accuracy: 0.995850622406639  
(Epoch 45 / 50) Training Accuracy: 0.9940064545873675  
(Epoch 46 / 50) Training Accuracy: 0.995850622406639  
(Iteration 10001 / 10800) loss: 4.144343587853944  
best performance 99.72337482710927%  
(Epoch 47 / 50) Training Accuracy: 0.9972337482710927  
(Epoch 48 / 50) Training Accuracy: 0.9963116643614569  
(Iteration 10501 / 10800) loss: 7.250060655642001  
(Epoch 49 / 50) Training Accuracy: 0.995850622406639  
(Epoch 50 / 50) Training Accuracy: 0.9972337482710927

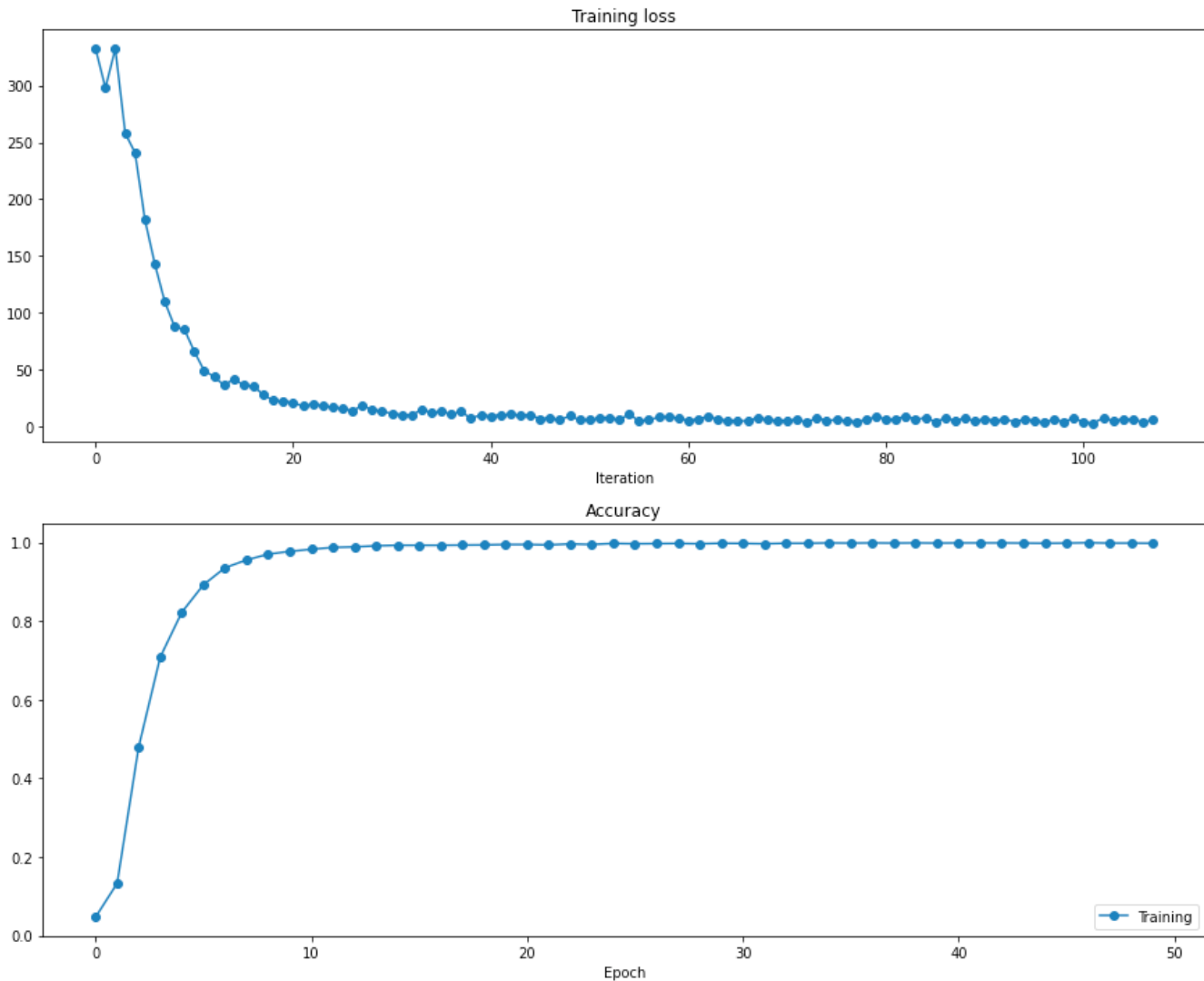


## 1.2 LSTM

```
(Iteration 1 / 10800) loss: 332.827350539917
best performance 3.872752420470263%
(Epoch 1 / 50) Training Accuracy: 0.03872752420470263
best performance 12.678653757491931%
(Epoch 2 / 50) Training Accuracy: 0.1267865375749193
(Iteration 501 / 10800) loss: 186.01998583478021
best performance 43.337943752881515%
(Epoch 3 / 50) Training Accuracy: 0.43337943752881514
best performance 66.0673121254034%
(Epoch 4 / 50) Training Accuracy: 0.6606731212540341
(Iteration 1001 / 10800) loss: 62.07865116710438
best performance 79.3453204241586%
(Epoch 5 / 50) Training Accuracy: 0.7934532042415859
best performance 87.45965882895344%
(Epoch 6 / 50) Training Accuracy: 0.8745965882895343
(Iteration 1501 / 10800) loss: 36.334608514481076
best performance 91.97786998616874%
(Epoch 7 / 50) Training Accuracy: 0.9197786998616874
best performance 95.0207468879668%
(Epoch 8 / 50) Training Accuracy: 0.950207468879668
best performance 96.63439372982941%
```

(Epoch 9 / 50) Training Accuracy: 0.9663439372982942  
(Iteration 2001 / 10800) loss: 21.209863662358288  
best performance 97.74089442139234%  
(Epoch 10 / 50) Training Accuracy: 0.9774089442139234  
best performance 98.38635315813738%  
(Epoch 11 / 50) Training Accuracy: 0.9838635315813739  
(Iteration 2501 / 10800) loss: 18.381621759417605  
best performance 98.66297833102813%  
(Epoch 12 / 50) Training Accuracy: 0.9866297833102813  
best performance 99.03181189488244%  
(Epoch 13 / 50) Training Accuracy: 0.9903181189488244  
(Iteration 3001 / 10800) loss: 11.247386892033091  
(Epoch 14 / 50) Training Accuracy: 0.9903181189488244  
best performance 99.12402028584602%  
(Epoch 15 / 50) Training Accuracy: 0.9912402028584602  
best performance 99.35454126325496%  
(Epoch 16 / 50) Training Accuracy: 0.9935454126325496  
(Iteration 3501 / 10800) loss: 10.959392268122736  
best performance 99.44674965421854%  
(Epoch 17 / 50) Training Accuracy: 0.9944674965421854  
best performance 99.53895804518211%  
(Epoch 18 / 50) Training Accuracy: 0.9953895804518211  
(Iteration 4001 / 10800) loss: 9.68625175236408  
(Epoch 19 / 50) Training Accuracy: 0.9953895804518211  
(Epoch 20 / 50) Training Accuracy: 0.9953895804518211  
(Iteration 4501 / 10800) loss: 8.585711715626424  
best performance 99.5850622406639%  
(Epoch 21 / 50) Training Accuracy: 0.995850622406639  
best performance 99.63116643614569%  
(Epoch 22 / 50) Training Accuracy: 0.9963116643614569  
(Epoch 23 / 50) Training Accuracy: 0.9963116643614569  
(Iteration 5001 / 10800) loss: 8.600811702597746  
(Epoch 24 / 50) Training Accuracy: 0.995850622406639  
best performance 99.67727063162748%  
(Epoch 25 / 50) Training Accuracy: 0.9967727063162748  
(Iteration 5501 / 10800) loss: 8.254797404108333  
(Epoch 26 / 50) Training Accuracy: 0.995850622406639  
(Epoch 27 / 50) Training Accuracy: 0.9967727063162748  
(Iteration 6001 / 10800) loss: 5.088492215057814  
best performance 99.72337482710927%  
(Epoch 28 / 50) Training Accuracy: 0.9972337482710927  
(Epoch 29 / 50) Training Accuracy: 0.9972337482710927  
(Epoch 30 / 50) Training Accuracy: 0.995850622406639  
(Iteration 6501 / 10800) loss: 4.429147169788172  
(Epoch 31 / 50) Training Accuracy: 0.9972337482710927  
(Epoch 32 / 50) Training Accuracy: 0.9972337482710927  
(Iteration 7001 / 10800) loss: 5.783688207041484  
(Epoch 33 / 50) Training Accuracy: 0.9972337482710927  
(Epoch 34 / 50) Training Accuracy: 0.9967727063162748  
(Iteration 7501 / 10800) loss: 6.4836521382612515  
best performance 99.76947902259106%  
(Epoch 35 / 50) Training Accuracy: 0.9976947902259106  
(Epoch 36 / 50) Training Accuracy: 0.9972337482710927  
best performance 99.81558321807285%  
(Epoch 37 / 50) Training Accuracy: 0.9981558321807285  
(Iteration 8001 / 10800) loss: 7.227241271390527  
(Epoch 38 / 50) Training Accuracy: 0.9976947902259106  
(Epoch 39 / 50) Training Accuracy: 0.9976947902259106  
(Iteration 8501 / 10800) loss: 5.900491932929593  
(Epoch 40 / 50) Training Accuracy: 0.9972337482710927  
(Epoch 41 / 50) Training Accuracy: 0.9981558321807285  
(Iteration 9001 / 10800) loss: 3.959986730685489  
best performance 99.90779160903642%

```
(Epoch 42 / 50) Training Accuracy: 0.9990779160903642
(Epoch 43 / 50) Training Accuracy: 0.9986168741355463
(Iteration 9501 / 10800) loss: 7.260487420821417
(Epoch 44 / 50) Training Accuracy: 0.9981558321807285
(Epoch 45 / 50) Training Accuracy: 0.9986168741355463
(Epoch 46 / 50) Training Accuracy: 0.9986168741355463
(Iteration 10001 / 10800) loss: 4.158684215646959
(Epoch 47 / 50) Training Accuracy: 0.9981558321807285
(Epoch 48 / 50) Training Accuracy: 0.9981558321807285
(Iteration 10501 / 10800) loss: 4.398654117353109
(Epoch 49 / 50) Training Accuracy: 0.9981558321807285
(Epoch 50 / 50) Training Accuracy: 0.9986168741355463
```



## 2. Sample text generation from a trained model

she was ever to get out again. suddenly she came upon a little three-legged table, all made of solid glass; there was nothing on it except a tiny golden key, and alice's first thought was that it might belong to one of the doors of the hall; but, alas! either the locks were too large, or the key was too small, but at any rate it would not open any of them. however, on the second time round, she came upon a low curtain she had not noticed before, and behind it was a little door about fifteen inches high: she tried the little golden key in the lock, and to her great delight it fitted! alice opened the door and found that it led into a small passage, not much larger than a rat-hole: she knelt down and looked along the passage into the loveliest garden you ever saw. how she longed to get out of that dark hall, and wander about among those beds of bright flowers and those cool

fountains, but she could not even get her head through the doorway; 'and even if my head would go through,' thought poor alice, 'it would be of very little use without my shoulders. oh, how i wish i could shut up like a telescope! i think i could, if i only knew how to begin.' for, you see, so many out-of-the-way things had happened lately, that alice had begun to think that very few things indeed were really impossible. there seemed to be no use in waiting by the little door, so she went back to the table, half hoping she might find another key on it, or at any rate a book of rules for shutting people up like telescopes: this time she found a little bottle on it, ['which certainly was not here before,' said alice,) and round the neck of the bottle was a paper label, with the words 'drink me' beautifully printed on it in large letters. it was all very well to say 'drink me,' but the wise little alice was not going to do that in a hurry. 'no, i'll look first,' she said, 'and see whether it's marked "poison" or not'; for she had read several nice little histories about children who had got burnt, and eaten up by wild beasts and other unpleasant things, all because they would not remember the simple rules their friends had taught them: such as, that a red-hot poker will burn you if you hold it too long; and that if you cut your finger very deeply with a knife, it usually bleeds; and she had never forgotten that, if you drink much from a bottle marked 'poison,' it is almost certain to disagree with you, sooner or later. however, this bottle was not marked 'poison,' so alice ventured to taste it, and finding it very nice, (it had, in fact, a sort of mixed flavour of cherry-tart, custard, pine-apple, roast turkey, toffee, and hot buttered toast,) she very soon finished it off. 'what a curious feeling!' said alice; 'i must be shutting up like a telescope.' and so it was indeed: she was now only ten inches high, and her face brightened up at the thought that she was now the right size for going through the little door into that lovely garden. first, however, she waited for a few minutes to see if she was going to shrink any further: she felt a little nervous about this; 'for it might end, you know,' said alice to herself, 'in my going out altogether, like a candle. i wonder what i should be like then?' and she tried to fancy what the flame of a candle is like after the candle is blown out, for she could not remember ever having seen such a thing. after a while, finding that nothing more happened, she decided on going into the garden at once; but, alas for poor alice! when she got to the door, she found she had forgotten the little golden key, and when she went back to the table for it, she found she could not possibly reach it: she could see it quite plainly through the glass, and she tried her best to climb up one of the legs of the table, but it was too slippery; and when she had tired herself out with trying, the poor little thing sat down and cried. 'come, there's no use in crying like that!' said alice to herself, rather sharply; 'i advise you to leave off this minute!' she generally gave herself very good advice, (though she very seldom followed it), and sometimes she scolded herself so severely as to bring tears into her eyes; and once she remembered trying to box her own ears for having cheated herself in a game of croquet she was playing against herself, for this curious child was very fond of pretending to be two people. 'but it's no use now,' thought poor alice, 'to pretend to be two people! why, there's hardly enough of me left to make one respectable person!' soon her eye fell on a little glass box that was lying under the table: she opened it, and found in it a very small cake, on which the words 'eat me' were beautifully marked in currants. 'well, i'll eat it,' said alice, 'and if it makes me grow larger, i can reach the key; and if it makes me grow smaller, i can creep under the door; so either way i'll get into the garden, and i don't care which happens!' she ate a little bit, and said anxiously to herself, 'which way? which way?', holding her hand on the top of her head to feel which way it was growing, and she was quite surprised to find that she remained the same size: to be sure, this generally happens when one eats cake, but alice had got so much into the way of expecting nothing but out-of-the-way things to happen, that it seemed quite dull and stupid for life to go on in the common way. so she set to work, and found so and she could not remember ever having seen such a thing. after a while, finding that nothing more happened, she decided on going into the garden at once; but, alas for poor alice! when she got to the door, she found she had forgotten the little golden key, and when she went back to the table for it, she found she could not possibly reach it: she could see it quite plainly through the glass, and she tried her best to climb up one of the legs of the table, but it was too slippery; and when she had tired herself out with trying, the poor little thing sat down and cried. 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### 3. Answers to inline questions about recurrent net behavior

**Ans:** While it seems that RNN converges a high accuracy faster than LSTM in the end LSTM reaches a higher accuracy. There are 2 ways to get >80% accuracy. The first one is increasing the learning rate 10 times and also doubling the number of epochs will allow us to output >80% accuracy.

Regarding the output, it seems like the text is very legible, well-formed and does not repeat sentences. The only problem are the special characters (some apostrophes shouldn't be in some places, there is one close bracket and a close parenthesis and so on).