

## 1 Introduction

- **Group members**

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- **Team name**

Caltech Earthquakes

- **Division of labour**

Kelsi implemented the HMM, and focused on improving it. She also did the preprocessing for the HMM, and the unsupervised algorithm. Sakthi implemented the RNN and worked on improvements for it, as well as the visualization and interpretation of the HMM.

## 2 Pre-Processing

## 3 Unsupervised Learning

## 4 Poetry Generation, Part 1: Hidden Markov Models

## 5 Poetry Generation, Part 2: Recurrent Neural Networks

### Initial Implementation

For our preprocessing for the RNN, we decided to first break down the text file by line, and for each line we parsed, we made sure the line was not empty (not just an endline character) and removed any special characters from it. For example, we wanted "Hello!" and "hello" to be processed as the same sequence of characters. We then finished each line with an endline character and added it to an accumulating string, which held the contents of the processed text file. After processing the input, we created dictionaries to convert each character found in the processed text to an integer, and a dictionary that converted integers to characters. We then generated a data set splitting this string into sequences of 40 consecutive characters, and converting the sequence of characters into a sequence of integers, and used the 41st character of the sequence as the y value, again, after converting it to an int.

We implemented a recurrent neural network using the Keras package for Python3. Using a sequential model, we had two dense LSTM layers of size 200, and one output layer. We calculated our loss using categorical cross-entropy loss, and 'adam' optimization. We also fine tuned our batch size, testing values of 32, 64, and 128. By observing the poems produced for these batch sizes after 10 epochs of training, we settled on a batch size of 64. We also fine-tuned the size of the dense layers, trying sizes of 100, 150, and 200, as suggested in the project details, and settled on a size of 200. We then trained this model for 125 epochs, converging to a loss of 0.4146 from a loss of 3.45 after the first epoch. To improve our model, we also looked at more complex RNN, using two dropout layers between the dense layers, and fine tuned the dropout probability to eventually choose 0.4. Initially, the model was only trained for 20 epochs, but we found that the loss still hadn't converged so we continued training until the loss did not improve for 2 epochs. We used a window size of 40 as the instruction suggested, but later moved to smaller window size of 25 in our attempts to improve our model.

To generate our poems, we used our seed sequence "Shall I compare thee to a summer's day?" and processed it, and for a sliding window of 40 characters, predicted the next letter in the sequence. Our model gives us an array of probabilities for the next character, given the previous 40 characters, so using this array of probabilities, we sample from the population of characters accordingly for a given diversity value. We also counted the number of newline characters that were predicted in the entire generation process, stopping after 14 newline characters, giving us 14 lines in the poem.

Despite training for so many iterations, our LSTM did not successfully learn sentence structure or sonnet structure, as we see in the poems below, few of the words produced are real words. However, for the brief segments of the poems that contain real words, it seems to follow some loose sentence structure. For example: "i love you" and "of the braid". As a result, the poem quality seems fairly low, and this is a direct result of the character-based nature of the neural network resulting in jumbled English. Because there are so many more sequences of characters than sequences of words, the RNN takes more training data to train, but both sets of training data were still generated from the same text file. It took much longer to train the RNN than to train the HMM, again, because it starts from a lower level of understanding, since we are working with characters instead of words.

## Poems

— diversity: 1.5

— Generating with seed: " shall i compare thee to a summers day

"

shall i compare thee to a summers day  
weat kerp tellv in these i would to hath  
my self iil iiddsu your thlltt my self brane ereed  
but ceatt that weal i love you be teildde  
and me altereasonse of the braid and lind  
which treals mind eye is is a lawvereo  
at tenmn lines bety paming iimeshsy  
or at dolg pdr tiat weaddddleditg tiink  
eor shamls iampeut sp will he's shcd might  
sevoy seep tidu thou 'liserpeas nor  
j thak oyck tine suelt so lem so ku haln  
and nock i tas of fold cach or pattry  
but be thy liate me thrugh mights me sn botn  
and in holaskeri hrln with the trwe doth green  
and confoundane farth in thee tie live"

— diversity: 0.75

— Generating with seed: " shall i compare thee to a summers day

"

shall i compare thee to a summers day  
when that wilt nottncry that fell asd feidt  
that it 'bol gor moctatd i do dispilts

and diary my self i'ck tren to the most  
but when your changent of this weil  
byt sickt his tputatt mot i loow more eeee  
to say toe borcmest whereup the bear  
thy presclv ceauiies ifart he lile artire  
for whose winter's enoling on the rulp're  
when sesimg a betteiry ocrure of thy deeds  
therefo thy putlok dead trealed thou art  
o what a worthsed wron delive no mane sehmnts  
oo aly of these falsehe move's fresh ceserity  
then the means me with vinter did stansed  
and dotnt and in habkt and it gaults light"

— diversity: 0.25

— Generating with seed: " shall i compare thee to a summers day  
"

shall i compare thee to a summers day  
aid uosthfr this wirte doth beauty stail  
thou mayst be thy oudsent'st a linit sade  
but when your count in these cannot chind  
o carve norer mine him though mews the even  
but day doth daily draw my sorrows line  
so thy freat gift woon be forgouingnl  
for higheo of line ow well my heart deegines  
so fotth the blow of with dupy steet selbit  
ald my hoade fyen siln liss lysbs'bd and were orisit  
oatt reason havd the stard or thy sweet graces  
beauteous all fellls tine world have erreemed  
more that my self but was donf iis oun  
gow many lambs kild and they acvodance seegng  
and all the dead no nore drtbl dole"

## 6 Additional Goals

### Haikus

We adapted our RNN to compose haikus. To do this, we created an file of haikus, where each line in a haiku is separated by a tab character, and each haiku is separated by a newline character. We also changed our window size from 40 characters to 15, since haikus are much smaller, and a 40 character seed would make up a significant portion of the poem. We continued to use dense layers of size 200. We then trained the RNN on this data set for about 100 epochs with a batch size of 64 (the batch size we found was effective for our sonnets). To generate our haikus, we used the same skeleton as the sonnets, just adjusting the win-

dow size. The results for the haikus were much more promising than the sonnets, which was surprising considering the training set was smaller. Here are some of our favorite haikus that were generated:

light snowy breath to read  
old tombstones hot wind shadows  
the roadrunner's beak

furled umbrella  
turns into a cane  
chernobyl vells

Of course, many of the haikus we generated often contained just jumbled letters, and when they did contain words, they rarely made sense, much like the haikus above. However, the model was able to predict syllable count fairly accurately, as you can see the first haiku follows the 5-7-5 pattern, and the second haiku is close. Given more time, we would have liked to experiment with the Word2Vec package and worked to predict words that were similar to the previous words in the sequence.

### More Complex RNNs

To improve our RNN, we decided to implement a more complex model. Instead of using two dense layers of size 200, we decided to include dropout layers as well to avoid overfitting. We also used a smaller window size of 25. Moreover, instead of predicting the character following a sequence, we trained the model to predict the character preceding the sequence. This was in preparation for us to generate rhyming poems.

Given the chance to do this again, we would have liked to also train with a validation set, and have stopped training when the validation loss stopped improving, instead of depending on the training loss. Here are the poems generated with this approach:

— Generating with end: ue by the grave and thee  
— Diversity: 0.25

and in this cold complaining  
she would have trained crie  
and in his and he like again  
my art thou art in me must roves to side thy state  
and in your offences fived in your devory  
of fathered bester and with dinkilling eye  
that she more living so offence alove  
in either kill of beauty tend  
and with a concestion makes her wind  
and with your shame to supretise is scapening on to love my love  
that my after for my days dad make the mettle wit  
against my valthrough it should nor gistless

cinfounded in a mined eyes  
the tongue by the grave and thee

— Diversity: 0.75

but loves her painted hend  
with whose what eyes now love to my  
and that can men shall heavenly for see only most to shows and toney  
to make the mudder's grace  
for thy sweet to time's eyes to hast  
but no so is my love to cay  
and to the humbers at the spirit on thee  
'didst thou the sefle but in his rain  
to from the best this true for then the eye alone  
even in my love com from that at the reason  
to lives my sorrow nature had't teou poy  
to fair thy loses she lacks and unneed the bound to make their sidness  
fit and the trembling eyes  
the tongue by the grave and thee

— Diversity: 1.5

i should in cartle's dame  
was fined in lidob giden kies  
then boldness her beauteous i will  
hinour to elmantinal condensmaking  
with those and burd nor let  
to prubify to leave th from it  
when shalt thou my have be end  
so do am state at living eye and heart it may be gone lix  
the other hours are so co civitate  
the colous o'erds to hell for love and bift from this all treed  
and when that gave to trespect thy state  
but were the had taught the cloud or all apay  
and in her hourffece baskys-are tongue by the grave and thee

## Rhyming

For our rhyming using the RNN, we used this implementation of the more complex RNN. Our first step was to generate a rhyming dictionary using the CMU dictionary and parsing each line of the sonnets. Using the CMU dictionary, we generated the pronunciations of each of the words in the Shakespearean texts, and compared the pronunciations of the ending of each of the words, so each word mapped to the pronunciation of its ending, and each pronunciation mapped to a list of words with that ending.

Now to generate the rhyming poem, we find the endings of each line and generate the preceding characters based on the word. First, we find 7 random words in the sonnets, and make these the ends of lines

1, 2, 5, 6, 9, 10, and 13. Then, we use our rhyming dictionary to choose a word that rhymes with the line endings of the aforementioned lines and make these words the endings of lines 3, 4, 7, 8, 11, 12, and 14, such that we have a *ababdcde f e f g g* rhyme scheme.

Below is one of the poems generated through this process:

Have women witagainst the cause but in the horn,  
The sparm'dall wither yet love me all contented stair,  
To beand croused could back their mildress' sky forlorn,  
Effects and dischance andmore beauty of thyself all stair.  
But his smokest love some is and now appear,  
With that praise for living chance or thy burn,  
Friendand for thee and steared berience more you peer,  
Lively and confounds his artand heavenly one can spurn.  
That true whan attening of her lind and horse,  
Thas thoosebut if the would be maunt the heart,  
Of all love's sout'st she dings with thy scarce,  
Eyesand never was so watch the for both's transport.  
To the priseand sily burupt make tears they sphere,  
Thoutment on that gave darefrown from the dangerous year.

## 7 Visualization and Interpretation