```python
import numpy as np
from tqdm import tqdm
import re


# Code to read csv file into Colaboratory:
!pip install -U -q PyDrive
from pydrive.auth import GoogleAuth
from pydrive.drive import GoogleDrive
from google.colab import auth
from oauth2client.client import GoogleCredentials
# Authenticate and create the PyDrive client.
auth.authenticate_user()
gauth = GoogleAuth()
gauth.credentials = GoogleCredentials.get_application_default()
drive = GoogleDrive(gauth)
```

▾ Load and preprocess

```python
# Load Shakespeare.txt
# Punctuation, including \n, included as separate "words"
# TODO: add syllable info
# TODO: HMM currently sucks, probably because I haven't done ^^^, and maybe because
# TODO: also easy to add rhyme (as in 'additional goals' section)
downloaded = drive.CreateFile({'id':'1cwaY0yRvUNgggFytJpca_1Mao85bawQN'})
downloaded.GetContentFile('filename.txt')

data = []
accum = []

f = open('filename.txt')

for line in f:
  if len(line) == 1:
    continue
  words = line.split()
  if len(words) == 1: # Line is only a number--beginning of new sonnet
    if len(accum) != 0:
      data.append(accum)
      accum = []
  else:
    for word in words:
      word = word.lower()
      # Case: no punctuation at the end
      if word[-1].isalpha():
        accum.append(word)
      # Case: last character is punctuation mark
      else:
        accum.append(word[:-1])
        accum.append(word[-1])
    accum.append('\n')
```

```
data = np.array([np.array(seq) for seq in data])
print(f'data.shape: {data.shape}')
print('')
print(f'data[0]: {data[0]}')
```

```
data.shape: (153,)

data[0]: ['from' 'fairest' 'creatures' 'we' 'desire' 'increase' ',' '\n' 'that'
 'thereby' "beauty's" 'rose' 'might' 'never' 'die' ',' '\n' 'but' 'as'
 'the' 'riper' 'should' 'by' 'time' 'decease' ',' '\n' 'his' 'tender'
 'heir' 'might' 'bear' 'his' 'memory' ':' '\n' 'but' 'thou' 'contracted'
 'to' 'thine' 'own' 'bright' 'eyes' ',' '\n' "feed'st" 'thy' "light's"
 'flame' 'with' 'self-substantial' 'fuel' ',' '\n' 'making' 'a' 'famine'
 'where' 'abundance' 'lies' ',' '\n' 'thy' 'self' 'thy' 'foe' ',' 'to'
 'thy' 'sweet' 'self' 'too' 'cruel' ':' '\n' 'thou' 'that' 'art' 'now'
 'the' "world's" 'fresh' 'ornament' ',' '\n' 'and' 'only' 'herald' 'to'
 'the' 'gaudy' 'spring' ',' '\n' 'within' 'thine' 'own' 'bud' 'buriest'
 'thy' 'content' ',' '\n' 'and' 'tender' 'churl' "mak'st" 'waste' 'in'
 'niggarding' ':' '\n' 'pity' 'the' 'world' ',' 'or' 'else' 'this'
 'glutton' 'be' ',' '\n' 'to' 'eat' 'the' "world's" 'due' ',' 'by' 'the'
 'grave' 'and' 'thee' '.' '\n']
```

```
# HMM expects sequences of integers, not strings

# mapping: character --> boolean array
mapping = {}
def get_mapping(k):
  v = mapping.get(k, len(mapping))
  if v == len(mapping):
    mapping[k] = v
  return v

X1 = np.array([np.array([get_mapping(k) for k in seq]) for seq in data])

mapping_rev = {v:k for k,v in mapping.items()}

print(f'X1.shape: {X1.shape}')
print('')
print(f'X1[0]: {X1[0]}')
```

```
X1.shape: (153,)

X1[0]: [ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14  6  7 15 16 17 18 19 20 2
 22  6  7 23 24 25 12 26 23 27 28  7 15 29 30 31 32 33 34 35  6  7 36 37
 38 39 40 41 42  6  7 43 44 45 46 47 48  6  7 37 49 37 50  6 31 37 51 49
 52 53 28  7 29  8 54 55 17 56 57 58  6  7 59 60 61 31 17 62 63  6  7 64
 32 33 65 66 37 67  6  7 59 24 68 69 70 71 72 28  7 73 17 74  6 75 76 77
 78 79  6  7 31 80 17 56 81  6 20 17 82 59 83 84  7]
```

```
# hmmlearn in particular expects a single list of all observations, and a separate
# Also, each observation should be a list
lengths = np.array([len(seq) for seq in X1])
X = np.concatenate(X1).reshape((-1, 1))
X,lengths
```

```
(array([[ 0],
        [ 1],
        [ 2],
        ...,
        [35],
        [84],
        [ 7]]),
 array([137, 145, 142, 132, 129, 139, 129, 145, 147, 143, 157, 143, 141,
        144, 138, 137, 153, 144, 144, 142, 147, 152, 144, 150, 135, 148,
        144, 143, 147, 145, 146, 141, 140, 151, 138, 144, 153, 143, 148,
        157, 143, 164, 153, 147, 141, 147, 154, 149, 143, 146, 154, 137,
        141, 147, 138, 147, 151, 147, 139, 139, 152, 142, 136, 139, 145,
        119, 140, 139, 153, 141, 153, 149, 154, 146, 145, 144, 139, 142,
        150, 147, 148, 136, 148, 149, 145, 143, 151, 149, 146, 156, 150,
        152, 148, 143, 144, 153, 140, 149, 160, 142, 150, 148, 147, 151,
        148, 144, 145, 148, 148, 153, 140, 149, 155, 143, 146, 138, 138,
        139, 144, 147, 149, 132, 149, 141, 139, 125, 142, 139, 149, 157,
        148, 140, 155, 156, 150, 159, 156, 147, 152, 149, 148, 151, 148,
        142, 126, 142, 141, 159, 150, 146, 151, 157, 140]))
```

HMM

HW6

Not used, since I convinced hmmlearn to work, and it's faster.

> ↳ *1 cell hidden*

hmmlearn

```
!pip install hmmlearn
from hmmlearn import hmm
```

```
Collecting hmmlearn
  Downloading https://files.pythonhosted.org/packages/ff/7b/33f629a443a067116...
     |████████████████████████████████| 368kB 3.3MB/s
  Requirement already satisfied: scipy>=0.15 in /usr/local/lib/python3.6/dist-pac
  Requirement already satisfied: numpy>=1.10 in /usr/local/lib/python3.6/dist-pac
  Requirement already satisfied: scikit-learn>=0.16 in /usr/local/lib/python3.6/
  Requirement already satisfied: joblib>=0.11 in /usr/local/lib/python3.6/dist-pa
  Installing collected packages: hmmlearn
  Successfully installed hmmlearn-0.2.3
```

Train model

```
clfs = {i : hmm.MultinomialHMM(n_components=i, n_iter=1000) for i in range(5, 20)}
for i, clf in clfs.items():
  clf.fit(X, lengths)
```

```
    print(f'{i}: {clf.monitor_}')
```

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```
5: ConvergenceMonitor(
    history=[-117140.65848116715, -117140.65265617566],
    iter=599,
    n_iter=1000,
    tol=0.01,
    verbose=False,
)
Fitting a model with 22707 free scalar parameters with only 22257 data points
6: ConvergenceMonitor(
    history=[-115450.10710809712, -115450.09954482393],
    iter=573,
    n_iter=1000,
    tol=0.01,
    verbose=False,
)
Fitting a model with 25959 free scalar parameters with only 22257 data points
7: ConvergenceMonitor(
    history=[-114657.96730195051, -114657.96028691951],
    iter=770,
    n_iter=1000,
    tol=0.01,
    verbose=False,
)
Fitting a model with 29213 free scalar parameters with only 22257 data points
8: ConvergenceMonitor(
    history=[-113149.32699599885, -113149.3177829113],
    iter=624,
    n_iter=1000,
    tol=0.01,
    verbose=False,
)
Fitting a model with 32469 free scalar parameters with only 22257 data points
9: ConvergenceMonitor(
    history=[-112450.15054044682, -112450.14195733756],
    iter=591,
    n_iter=1000,
    tol=0.01,
    verbose=False,
)
Fitting a model with 35727 free scalar parameters with only 22257 data points
10: ConvergenceMonitor(
    history=[-111011.12261585622, -111011.11464468834],
    iter=536,
    n_iter=1000,
    tol=0.01,
    verbose=False,
)
Fitting a model with 38987 free scalar parameters with only 22257 data points
11: ConvergenceMonitor(
    history=[-111293.49551457573, -111293.48716570067],
    iter=586,
    n_iter=1000,
    tol=0.01,
    verbose=False,
)
Fitting a model with 42249 free scalar parameters with only 22257 data points
12: ConvergenceMonitor(
    history=[-110429.10679414927, -110429.09716441242],
    iter=791,
    n_iter=1000,
    tol=0.01,
```

```
          verbose=False,
      )
      Fitting a model with 45513 free scalar parameters with only 22257 data points
      13: ConvergenceMonitor(
          history=[-109501.7632713553, -109501.75341183317],
          iter=584,
          n_iter=1000,
          tol=0.01,
          verbose=False,
      )
      Fitting a model with 48779 free scalar parameters with only 22257 data points
      14: ConvergenceMonitor(
          history=[-108875.06362502229, -108875.05634994658],
          iter=627,
          n_iter=1000,
          tol=0.01,
          verbose=False,
      )
      Fitting a model with 52047 free scalar parameters with only 22257 data points
      15: ConvergenceMonitor(
          history=[-108678.64488570648, -108678.63732834271],
          iter=635,
          n_iter=1000,
          tol=0.01,
          verbose=False,
      )
      Fitting a model with 55317 free scalar parameters with only 22257 data points
      16: ConvergenceMonitor(
          history=[-108618.66443182819, -108618.65521085338],
          iter=535,
          n_iter=1000,
          tol=0.01,
          verbose=False,
      )
      Fitting a model with 58589 free scalar parameters with only 22257 data points
      17: ConvergenceMonitor(
          history=[-106947.48359551704, -106947.47460141065],
          iter=624,
          n_iter=1000,
          tol=0.01,
          verbose=False,
      )
      Fitting a model with 61863 free scalar parameters with only 22257 data points
      18: ConvergenceMonitor(
          history=[-108382.76741593833, -108382.76026907515],
          iter=471,
          n_iter=1000,
          tol=0.01,
          verbose=False,
      )
      19: ConvergenceMonitor(
          history=[-106746.44039315278, -106746.4357206425],
          iter=821,
          n_iter=1000,
          tol=0.01,
          verbose=False,
      )


  # Generate sonnet
  for i, clf in clfs.items():
```

```
  sonnet, _ = clf.sample(len(data[1])) # Returns ([observations], [states])
  sonnet = sonnet.reshape(len(sonnet)) # Each observation is a list; extract it
  sonnet = ' '.join(mapping_rev[i] for i in sonnet)
  print(f'{i}: {sonnet}\n\n')
```

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```
5: therefore vile me :
 this by i for dates .
 what will me ?
 should of knife .
 so and ,
 minds , the fist of deceive ,
 times which so her roses but publish , nor churls such her no the laws ,
 for my hate to nature's sport now she move
 and , bright time no he dote ,
 thank hour travail soul mind crowned monument upon patient taught nature then
 all merit why were their and looks , and on the in will can
 and home which for mouthed proud
 for a my best, guess provide i ye , beauty that but his ornament ,
 die i you comments at being could the own are


 6: the of high rare
 intend but of of my monument bent ,
 that me mistaking . ! 'tis all thought
 wild me that and me more white ,
 whilst out hearsay name ,
 who sing potions what shame ,
 making comments tongue mark ' prove
 o that keen : loves cannot aggravate true ,
 seemed incertainties that mind and to with child me ,
 to when the all me humble large the time thee .
 a true fade ,
 thy dear her of be decays ,
 a life given face takes world you ,
 all love's you you . by hast for the already in youth note
 made is dost changing not ,
 joy poor not all praises so me youth , so thee since my your read , annexed


 7: then the love , and but not and extreme here
 than i my come thy dignified .
 doth show thine false-speaking do to they world thy admire that love . are ma
 doth call : and let of first give unswayed for you then then thou to height be
 and needs will make is pace thy parts whose pour'st give , and dost what you
 then dwellers heaven mouthed
 dost hue shall forced tyrants hope . such the thee ,
 but confounds ,
 which art am i thou quickly you the strange were



 8: usurer mine lease i what with in the art , thrivers form would away ,
 yet i painter frown'st others ' do thee i more when is that (dear of in bare
 not in tongue-tied thee ,
 nor all to beauty hath straight .
 to look hearts do themselves not so though have do thee , she perceive me sho
 that i his canker sees inconstant to my shalt drowns new ?
 than the , the look time's time ,
 the , their trust ,
 a in do do most stamp of war ' alone ,
 compare what therefore lips ,
 for frank thy fate ,
 your self her state ,
 that you virtue grows foes ,
 to dost nor my ,
 tired mine
```

9: i with of far when crave , tops so yet nature's eyes ward ,
 but the pierced far bait have ,
 harsh aggravate this hope :
 as tells mine those ,
 his delight betray and return clouds of sick to is beauty's art twice i full
 persuade of graces buried here
 come yet their hush profane thou this tanned be of head ? his madness dwells
 in still their worth , time's for small shop thou other wert treason !
 thou is drugs thee in this more ,
 and in these barren spend
 is wait of that self the may ' light ,
 my got ,
 but the more accessary to motley dying then thou pleased embassage
 and pretty hath new .
 to stelled , and

10: thy i live ,
 or still ill-used the a taste , or tells my i i this part in the spheres , bo
 and to settled worths worms) or in haste all , but my more ,
 of female sweet brow , and thy debt , breach and lifts enough needs now , ran
 sings thy salve ;
 how rid those the them rarities of banks tendered
 which many my wit the
 me love's be due of present praise ,
 whilst make reasons be modern feed but prove lose part ,
 thy canst love return on groan kind ,
 but muse ?
 and answer alters find ?
 that fawn hue . to love's since ,
 then by she thee as controlling ,

11: and o this ,
 and thence all thy violet your sake ocean .
 of red of true in love extreme ,
 in she adverse shouldst eye are
 and my night in me twofold lost .
 o remembered odours misuse not ,
 and i self you not that speak ,
 if then why it believe woe spot thy receipt of own . but i seen ,
 if my rite , thou you name heaven of princes shade with sweet sadly i self wh
 but sadly the cannot tongue-tied .
 why and yet make on i life away you which she love not ,
 who eyes cannot tongue-tied ,
 th upon to my self to white that prey hath is way , in must moan ,
 that love .
 to vanished

12: this so , without my lion's wastes gone , and sets poison 'truth that of m
 and to art all living scythe that object .
 herein parts his thought :
 when call thy unrest :
 thou i at muse to my wish worms well of good heir .
 how becomes here effect . nor as what sap time from black live remain
 blest taught as unthrifty the poisoned ,
 my thy power being die , sings i nothing when worthy art doth what could less
 and lest thou a , with my favour , but i blessed breasts queen , beauty eithe

13: in the own you one eye to blind , and loving mine which see ,
 and see is your true ,
 and all care her love tempting to i which this astronomy ,
 body's he , i sad from time's tell ,
 they i poverty for it state ,
 so garments things kinds and bear .
 thou having .
 and pluck could committed ,
 still in lively sake , that is think of time ,
 when me of in thy alone ,
 no eyes true rite , all thy powerful are ,
 as thee time time ,
 as is me very should
 to woe ,
 take disdain , thy beauty with free ,
 all constant cars , this accuse eve's she all my farther sway ,
 the beauty of

14: speak will thou brought ;
 outward hunted ,
 or never this spite , thou few each not be rich sum something dead confounds
 the abundance many , that o'er i this worth
 then i you this appear ?
 the concord , despite that quite doth white .
 or should had thee in things beard more .
 o happy no constant put infection their sight ,
 and make be i verse ,
 how wit in o'erpressed his death ,
 than me was some of of speed more thy elsewhere ,
 tell absence you) of i good .
 strikes will it night my the tongue ,
 the saw , creatures gentle importune is part .
 in testy the right abuse love we thy no birth to have thy crystal dearer ,

15: it again poesy love of the music gay ,
 and action , and in it steal breath the glory being sing ,
 or the unkind lends of how ,
 take tell sweets took .
 thy if that heart morning my muse ,
 and all him as am o'er i is the title be ,
 so i that a love's , but the mud ,
 in , to like no life on seasons looks hue , him this of vacant to i whereon m
 even in then betray despite it injuries ,
 so is religious thoughts dost sweets from they then greater sit .
 i all him alone oaths out gold trees thinking made painful ?
 which by thy book ,
 entitled careful will heart gives love which

16: may eyes to behold ,
 if found crying for churl writ .
 she truth false thrivers , before thy throned hand , in rich :
 and comfort ere this subjects bait . the praise too ; like than my outlive he
 that i thou rhyme ,
 fair a be him early
 and pleasure is kind , honey thy truth none ,
 as kings ,
 shows those is lamb cannot ,
 and mind

and mind ,
so actor walk live .
o so i done .
since more far maladies it .
and feel gentle praise ,
to in thy table of hands with cross .
for stay a self-willed commits ,
my will thou sun's woe ,
is reason unseeing crime ,
strength my sooner

17: thy pain cannot , that my fade , yet his your tell ,
 nor if do he place , and then me or alone ,
 o time my youth's why a incertainty ,
 for true so him can in say ,
 distilled my crown graces in their day .
 do charactered his write eyes all as methinks not fuel ,
 and leaves a love i'll in great , as seen ,
 and half my watchman to be .
 is never-resting pricked scythe lips and idol so .
 but becomes her bareness this thought .
 through sealed on you but he thy fled .
 from i what user me true derive .
 o sin since i their verse ,
 save some his not what wrinkle with mourners war .
 to all no

18: to-morrow dost thorns grew ,
 nor you more nor worth's angel holds much when whether thy any so to majesty
 as heaven's meadows fire .
 and you be of time me leaves my show ?
 to art in knowledge on must from me thee !
 like) gardens my former sweet speak hand ,
 thou but , to dye .
 so say of them ,
 your insufficiency doth thus ? sold or summer of my matter ,
 for will new perfection now with shall amends ,
 then lips torn ,
 that tenure ' willing yet sweets to the canker to moan ,
 nor slavery of lawful can took is daily a but pencil ?
 how you excuse (inferior up words thee ,
 that i be , so for she breathes

19: but wond'ring by stol'n done her ocean .
 and man reviewest spurring , are as worth
 to dull vows ,
 nor you with afford or most that so mind proud
 some by of case my blush , or thine gay ,
 now niggard wiry shadows part purpose knife ,
 which am seeing me ,
 but bending shadow subject to wilt praise truth enemies in losing loss ,
 why resty with outward edge thou ne'er-cloying boat ?
 since a my make love's rearward we away ,
 for tyrants one day doth forsaken :
 for can as life this my thy self your a hell :
 suns never hath sole eye and which right a beside ,
 but shape my crying house ,
 if war patience child was me going ,
 nor