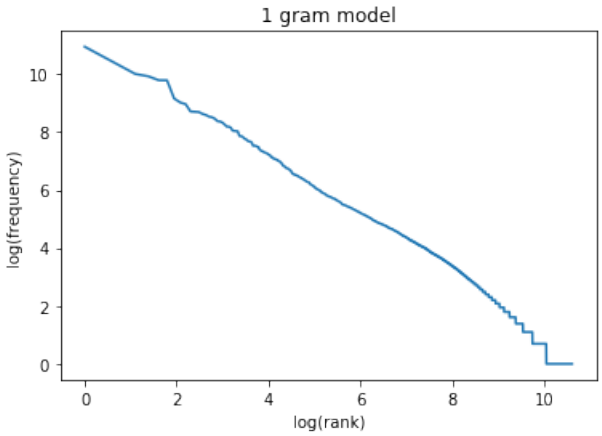
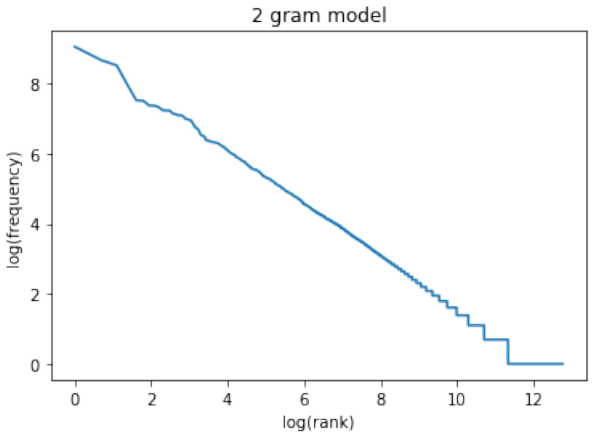
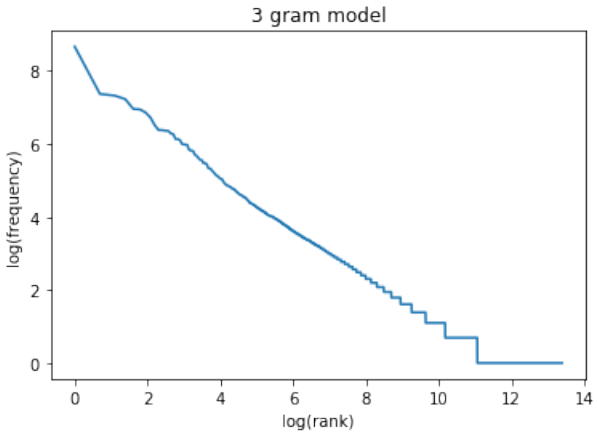
SUB PART 1 - Zipf's law verification

From Zipf's law : $f \propto \frac{1}{r}$
$f * r = constant$
$\log f + \log r = constant$
$\log f = -\log r + constant$







SUB PART 2 - Top 10 N-grams

Top 10 unigrams:

(('the',), 56448)
(('of',), 31276)
(('and',), 22092)
(('to',), 20341)
(('a',), 17780)
(('in',), 17705)
(('is',), 9474)
(('that',), 8240)
(('for',), 7788)
(('it',), 6051)

Top 10 bigrams:

(('of', 'the'), 8508)
(('<s>', 'the'), 5798)
(('in', 'the'), 4985)
(('to', 'the'), 2819)
(('and', 'the'), 1848)
(('on', 'the'), 1821)
(('for', 'the'), 1591)
(('<s>', 'in'), 1585)

(('<s>', 'it'), 1516)
(('it', 'is'), 1390)

Top 10 trigrams:

(('<s>', '<s>', 'the'), 5798)
(('<s>', '<s>', 'in'), 1585)
(('<s>', '<s>', 'it'), 1516)
(('<s>', '<s>', 'he'), 1377)
(('<s>', '<s>', 'this'), 1052)
(('<s>', '<s>', 'but'), 1038)
(('<s>', '<s>', 'a'), 955)
(('<s>', '<s>', 'and'), 831)
(('<s>', '<s>', 'i'), 675)
(('<s>', '<s>', 'they'), 590)

SUB PART 3 - Log Likelihood and Perplexity Score over testcases

Below models are run on these test examples :
'he', 'lived', 'a', 'good', 'life',
'the', 'man', 'was', 'happy',
'the', 'person', 'was', 'good',
'the', 'girl', 'was', 'sad',
'he', 'won', 'the', 'war'

Loglikelihood for unigram model:

[-32.83424838102342, -24.091989655768156, -23.4166871259785, -27.32603162480786, -24.734905768951318]

Loglikelihood for bigram model:

[-26.86317000488739, -22.339591199881653, -24.838201556634292, -inf, -21.15431998899194]

Loglikelihood for trigram model:

[-inf, -inf, -inf, -inf, -15.995702002744252]

Perplexity for unigram model:

[0.0014062204912880043, 0.002422397773280329, 0.0028679098737995246, 0.0010792295131443134, 0.0020627268823580876]

Perplexity for bigram model:

[0.004641888454787715, 0.003754133422712128, 0.0020101410421309316, inf, 0.005048924658664008]

Perplexity for trigram model:

[inf, inf, inf, inf, 0.01833532960709163]

Assignment Part 2 - Laplace Smoothing

Below models are run on these test examples :
'he', 'lived', 'a', 'good', 'life',
'the', 'man', 'was', 'happy',
'the', 'person', 'was', 'good',
'the', 'girl', 'was', 'sad',
'he', 'won', 'the', 'war'

Inference: Performance degrades with increasing Laplace constant.

Laplace Constant : 0.0001

Loglikelihood for unigram model:

[-32.834746262759, -24.092387694914404, -23.417086174791734, -27.326424651312145, -24.73530387061002]

Loglikelihood for bigram model:

[-26.95176691962215, -22.4215321021218, -24.8783195499466, -35.28121184282719, -21.2340140486702]

Loglikelihood for trigram model:

[-48.056460667126736, -34.873904683648725, -35.024301836829885, -36.82021816036394, -17.549621990505962]

Perplexity for unigram model:

[0.0014060804719596 67, 0.0024221567329880747, 0.0028676237790625806, 0.001079123476903062, 0.0020625215988253906]

Perplexity for bigram model:

[0.004560361492511085, 0.0036780115021154158, 0.0019900810996430875, 0.0001477036050642606 58, 0.0049493277873057994]

Perplexity for trigram model:

[6.696823647655817e-05, 0.0001635362023702623 3, 0.0001575015183846695 2, 0.0001005299826541490 4, 0.012432944715356702]

Laplace Constant : 0.001

Loglikelihood for unigram model:

[-32.83922495016433, -24.095968248693975, -23.420675815456175, -27.32996009277662, -24.738884986977126]

Loglikelihood for bigram model:

[-27.57949052214715, -22.982879841217674, -25.198449120216807, -34.36277391875188, -21.798876178603518]

Loglikelihood for trigram model:

[-47.48395016865736, -35.257292068140536, -35.89132398864079, -39.83687900149157, -21.537488157082798]

Perplexity for unigram model:

[0.0014048215568924153, 0.0024199895374915326, 0.002865051498698575, 0.0010781701038180861, 0.0020606758926959615]

Perplexity for bigram model:

[0.004022313258438062, 0.003196432418563176, 0.0018370168870582356, 0.000185827175589574 5, 0.0042975119301188955]

Perplexity for trigram model:

[7.509248778199658e-05, 0.0001485895104949571, 0.0001268086884816192, 4.728961936127632e-05, 0.004587720326082994]

Laplace Constant : 0.01

Loglikelihood for unigram model:

[-32.88379072368735, -24.13159690954856, -23.456395333476458, -27.365137775214055, -24.77451927127337]

Loglikelihood for bigram model:

[-30.223692391114643, -25.06582382115037, -26.910112293042992, -35.482481560924576, -24.060599831541595]

Loglikelihood for trigram model:

[-49.88941160326865, -38.58944042024911, -39.57718998337484, -44.21534495761073, -29.066705800378298]

Perplexity for unigram model:

[0.0013923558021514107, 0.002398530004547257 4, 0.002839580828306346, 0.001068729794307094, 0.0020423997431042017]

Perplexity for bigram model:

[0.002370300643168069, 0.0018989466234006487, 0.0011974894086604388, 0.000140455423466695 95, 0.0024414822175878965]

Perplexity for trigram model:

[4.641525781091414e-05, 6.459586845265215e-05, 5.046162074610827e-05, 1.5826319077130773e-05, 0.000698429405594697]

Laplace Constant : 0.1

Loglikelihood for unigram model:

[-33.30870752682203, -24.471291120260428, -23.796996949108927, -27.700336616381716, -25.114269473477272]

Loglikelihood for bigram model:

[-36.21855054341226, -29.317741128330834, -31.065751514978366, -38.07733662405666, -28.62157925834711]

Loglikelihood for trigram model:

[-55.12612222826344, -43.5270098579958, -44.52756214051961, -49.12329885182458, -38.96406984927926]

Perplexity for unigram model:

[0.0012789171887368912, 0.002203247699630613 6, 0.0026077976208990715, 0.000982820406306255 5, 0.0018760864106040253]

Perplexity for bigram model:

[0.0007146553862849615, 0.000655943905829411 1, 0.0004237199235148975, 7.341853336802272e-05, 0.0007806412859571138]

Perplexity for trigram model:

[1.6285678668446664e-05, 1.8798143095943744e-05, 1.4637987347728277e-05, 4.639867663379853e-06, 5.882065658300917e-05]

Laplace Constant : 1

Loglikelihood for unigram model:

[-36.27920152752997, -26.845328323359098, -26.179993069333047, -30.030805343716295, -27.488842731794616]

Loglikelihood for bigram model:

[-44.84569996153263, -35.98692274903626, -37.36846750466741, -42.033583729302975, -35.46543785693498]

Loglikelihood for trigram model:

[-61.50885898889724, -49.948556485876885, -50.47066210038483, -54.15842061297218, -48.94623303501051]

Perplexity for unigram model:

[0.0007060388416337418, 0.001217041846214115, 0.0014372865729122277, 0.0005488412414677287, 0.0010361838567876675]

Perplexity for bigram model:

[0.00012727760482017606, 0.00012381392957789048, 8.7653687550773e-05, 2.7306223019279004e-05, 0.00014105517046341436]

Perplexity for trigram model:

[4.5436868327046525e-06, 3.7748907296540824e-06, 3.312698834770587e-06, 1.317723207737269e-06, 4.849871933862789e-06]

Assignment Part 3 - Good-Turing Method

Below models are run on these test examples :
'he', 'lived', 'a', 'good', 'life',
'the', 'man', 'was', 'happy',
'the', 'person', 'was', 'good',
'the', 'girl', 'was', 'sad',
'he', 'won', 'the', 'war'

Inference:
Naive implementation of this method fails mainly because of 2 ways:
1. Cases where $n_{r+1} = 0$
2. Case where $n_{r+1} = 0$ because of r being the highest frequency.

Loglikelihood for unigram model:

[-32.83424838102342, -24.091989655768156, -23.4166871259785, -27.32603162480786, -24.734905768951318]

Loglikelihood for bigram model:

[-inf, -inf, -inf, -inf, -inf]

Loglikelihood for trigram model:

[-84.30398062496148, -50.35520597619277, -51.450965195878474, -56.213139130676225, 13.656538272857798]

Perplexity for unigram model:

[0.0014062204912880043, 0.002422397773280329, 0.0028679098737995246, 0.0010792295131443134, 0.0020627268823580876]

Perplexity for bigram model:

[inf, inf, inf, inf, inf]

Perplexity for trigram model:

[4.758272199069103e-08, 3.409988994654197e-06, 2.592880082845027e-06, 7.883806678796675e-07, 30.390637020150237]

Assignment Part 4 - Interpolation Method

Below models are run on these test examples :
['he', 'lived', 'a', 'good', 'life']
['the', 'man', 'was', 'happy']
['the', 'person', 'was', 'good']
['the', 'girl', 'was', 'sad']

['he', 'won', 'the', 'war']

Inference: The performance increases with increasing λ value.
Inference: λ for bigram interpolation; λ_1 and λ_2 for trigram interpolation.

Using Interpolation smoothing with $\lambda =$ 0.2 $\lambda_1 =$ 0.2 $\lambda_2 =$ 0.2

Loglikelihood for bigram model:
[-32.66246276441453, -26.719690688001492, -27.40283499806891, -31.35563915688864, -26.34077593024058]

Loglikelihood for trigram model:
[-32.5385828001288, -27.343571554618293, -27.430526465475456, -32.10895968229792, -22.62987957833191]

Perplexity for bigram model:
[0.0014553737290567707, 0.001255875083115597, 0.0010587050702298892, 0.0003940984569206907 4, 0.001380659517754312]

Perplexity for trigram model:
[0.0014918824606549154, 0.0010745074712685315, 0.001051401107345643, 0.0003264479889949162, 0.00349133918903733]

Using Interpolation smoothing with $\lambda =$ 0.5 $\lambda_1 =$ 0.3 $\lambda_2 =$ 0.3

Loglikelihood for bigram model:
[-29.534955832872953, -24.49074549396976, -26.05971719767102, -30.166311778821427, -23.681408966578573]

Loglikelihood for trigram model:
[-30.688418095326107, -25.75476772679707, -26.59521806071914, -31.172438283723096, -20.573328581211484]

Perplexity for bigram model:
[0.002720359695092117, 0.002192558014811939, 0.0014811606146854987, 0.0005305597669526547, 0.0026842545041897373]

Perplexity for trigram model:
[0.0021599210280007055, 0.0015984962559419142, 0.0012955700143163684, 0.0004125679778698260 4, 0.005838203523509511]

Using Interpolation smoothing with $\lambda =$ 0.8 $\lambda_1 =$ 0.5 $\lambda_2 =$ 0.5

Loglikelihood for bigram model:
[-27.742016099604488, -23.07769266612461, -25.251662024964457, -30.023842061623544, -22.012408138365345]

Loglikelihood for trigram model:
[-28.474571723720764, -23.538020160919725, -25.811653927371488, -inf, -17.845886921150193]

Perplexity for bigram model:
[0.003893669616337511, 0.0031215576138428095, 0.0018127404712529286, 0.0005497975076672671, 0.004074113774500785]

Perplexity for trigram model:
[0.0033630252275713628, 0.0027822229730231503, 0.001575924047619089, inf, 0.011545359123063854]