

NLP HOMEWORK1 REPORT

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Assumptions and code analysis

In order to do this project, I made the following assumptions,

1. I regard each line of those files as a sentence.
2. Not only letters, but every character in those files is also regarded useful. For example, characters such as “! , . : ?” and numbers are also in count.
3. The n-gram model is designed for characters, not words. For example, “apple” would not be regarded as a word but 5 letters. So for the unigram model, it would be a,p,p,l,e. For the bigram model, it would be ap, pp,pl,le.
4. In order to predict the language of the test file. I would predict it sentence by sentence rather than calculate the probability of the whole article.
5. Based on my prediction of each model, the test file is an English article, so I only calculated the perplexity based on the English dataset.

Now, I would describe how I wrote the Java code to implement those models.

I used Java to develop this project, my Java version is JDK 1.11. First of all, I created four classes Ngram, NgramCount, Path, and Main. Ngram includes all functions to build and evaluate each model. NgramCount includes two attributes token and type. Path includes the paths of each file I will use or generate. Main is the process of running this project. I will describe each function and attribute.

In the Ngram class:

- getSentences:

This function would read a file line by line, save each line as a String and store all of them into an ArrayList and return this ArrayList.

- getNgramCount:

This function takes three inputs, int k is the k gram model, String language is the language type of the input file and String path is the path of that file. It would count the k gram words and write the result into a txt file. All counts (unigram bigram and

trigram) of the same language would be written into the same txt. So, after running this function 6 times (3 times for each language), three txt file would be generated and saved in the result folder.

- `getNgram`:

This function would read the file generated by the last function and save the result as a hashmap.

- `Predict`:

This function would use general n-gram models to predict the language of the test file. The inputs of this function are three hashmaps for three languages, int k as the k gram model, the path of the test file, three NgramCount objects for three languages which include the number of characters of unigram (token) and the number of different types of characters of unigram model(type). This function would first call `getSentences` function to get all sentences of the test file. Then, for each sentence, this function would call `getProb` function to calculate the probabilities of each sentence to be English, Spanish, and German. Then it will compare those three probabilities and regard this sentence to be the language with the largest probability. It would also calculate the perplexity of this sentence based on the English model. After doing this for all sentences, it would predict this article as the language with most of the sentences. And calculate the average perplexity of this article.

- `getPorb`:

This function is used to calculate the probability of a sentence to be one language based on the k gram model.

- `laPlacePredict`:

This function will do the same thing with the predict function but it will use LaPlace smoothing trigram model to calculate the probability.

- `getLaPlaceProb`:

This function would calculate the probability of a sentence to be one language based on LaPlace smoothing trigram model.

- `backoffPredict`:

This function will do the same thing with the predict function but it will use backoff smoothing trigram model to calculate the probability.

- `getBackoffProb`:

This function would calculate the probability of a sentence to be one language based on backoff smoothing trigram model.

- linearInterPredict:

This function will do the same thing with the predict function but it will use Linear Interpolation smoothing trigram model to calculate the probability.

- getLinearInterProb:

This function would calculate the probability of a sentence to be one language based on Linear Interpolation smoothing trigram model.

- absDisPredict:

This function will do the same thing with the predict function but it will use absolute discounting smoothing trigram model to calculate the probability.

- getAbsDisProb:

This function would calculate the probability of a sentence to be one language based on absolute discounting smoothing trigram model.

- getThProbs:

this function would use 4 trigram models to calculate the probabilities of all possible "th*" Strings. The result would be generated and saved in the result folder as thProb.txt.

In the NgramCount class:

There are two attributes, token means the number of characters in an n-gram model and type means the number of different characters in a gram model.

In the Main class:

This class is the entry of the code, the main function would call getNgramCount function 9 times to generate all n-gram counts. Then it will call getNgram function three times to get hashmaps for three different languages. After that, it will call all predict function to do the prediction and calculate the perplexity. Finally, it will call getThProbs function to get the history of th*.

"TH" probabilities

The n-gram count results and the th* probabilities result are saved in the result folder.

The output is large, so I will only show some important parts and attach the whole result in the attachment part.

```
vocabulary, trigram, LaPlace trigram, backoff trigram, linear interpolation trigram, absolute discount trigram
th , 0.05791829882484611, 0.056861672550439835, 0.05791829882484611, 0.10471968628387947
th!, 0.0, 2.733734145294875E-4, 2.5657143590204104E-5, 8.5523811967347E-6
th", 0.0, 2.733734145294875E-4, 7.69714307706123E-5, 2.56571435902041E-5
th%, 0.0, 2.733734145294875E-4, 8.980000256571437E-5, 2.9933334188571455E-5
th', 0.0, 2.733734145294875E-4, 1.721763085399449E-4, 2.797540139617505E-4
th(, 0.0, 2.733734145294875E-4, 2.2450000641428589E-4, 7.483333547142862E-5
th), 0.0, 2.733734145294875E-4, 2.56571435902041E-4, 8.5523811967347E-5
th,, 0.0016787912702853946, 0.0019136139890179038, 0.0016787912702853946, 0.005847030194070329
th-, 0.0, 2.733734145294875E-4, 1.721763085399449E-4, 5.320492592654242E-4
```

The image above is the header of my "th" probabilities result. I calculated it by using 4 models.

```
thä, 0.0, 2.733734145294875E-4, 3.2071429487755126E-5, 1.0690476495918375E-5
thé, 0.0, 2.733734145294875E-4, 1.2828571795102052E-5, 4.27619059836735E-6
thí, 0.0, 2.733734145294875E-4, 6.414285897551026E-6, 2.138095299183675E-6
thó, 0.0, 2.733734145294875E-4, 3.2071429487755126E-5, 1.0690476495918375E-5
sum, 1.0, 1.0, 1.12, 1.0]
```

The image above is the tail of my "th" probabilities result. The probability sums of trigram model, LaPlace smoothing trigram model, and Linear interpolation smoothing trigram model are 1. However, the probability sum of backoff smoothing model is larger than 1 because the backoff model needs to set the parameters to discount the probabilities of those existing words. It's hard and I am still trying to fix this.

Perplexity

The prediction and perplexity of each sentence generated by each model are printed on the console.

The result is also large, so I will only show the average perplexity of each model here and put the whole result in the attachment part.

This article is English
1gram perplexity: Infinity

For the unigram model, perplexity is infinity since there are some characters in the test case never show up in the English dataset.

```
- - -
This article is English
2gram perplexity: Infinity
```

Same for the bigram model.

This article is English
3gram perplexity: Infinity

Also same for the trigram model.

This article is English
Laplace trigram perplexity: 11.479380907072992

The result of Laplace smoothing is pretty good, the average perplexity is about 11.

This article is English
backoff trigram perplexity: 8.988186658940737

The backoff smoothing result is the best one. The average perplexity is about 9.

This article is English
Linear interpolation trigram perplexity: 11.117518958431667

The linear interpolation smoothing result is about the same as LaPlace. The average perplexity is also about 11.

This article is English
Absolute discount smoothing trigram perplexity: 10.750563197451966

The absolute discounting smoothing result is better than LaPlace. The average perplexity is about 10.

Results analysis

Based on my models, the best one for this project is the backoff smoothing trigram model. However, since the probability sum of this model is larger than 1. This model is invalid.

The other two models also performed well. Perplexity tells me the performance of each model. Since the dataset is not large enough, without smoothing, it is easy to get a 0 probability. In this case, the perplexity would be infinity. All smoothing models solved this problem.

When I checked the perplexity of each sentence. I found that there are more sentences with infinity perplexity in the bigram model and trigram model than in the unigram

model. It's quite easy to understand since in the unigram model, only some new characters would have a 0 probability. In the bigram or trigram model, some combination of existing characters would also be a new one. So, in order to get a good NLP model, two things are important. The first thing is to get a large dataset to include as many characters as possible. The second thing is to use a smoothing model to handle unexpected characters.

Since all three models without smoothing have the same perplexity. I cannot tell which model is the best. But based on what I learned from class, the trigram model should be better than the bigram and unigram model. If the dataset is larger, I think this project can get a conclusion.

Research task

In this part, I chose a smoothing method called absolute discounting. This method tries to decrease the probability of existing words just like give them a discount. Then give this probability to those not existing words.

The function to calculate a condition possibility is this:

$$p_{abs}(w_i|w_{i-n+1}^{i-1}) = \frac{\max\{c(w_{i-n+1}^i) - \delta, 0\}}{\sum_{w_i} c(w_{i-n+1}^i)} + (1 - \lambda_{w_{i-n+1}^{i-1}})p_{abs}(w_i|w_{i-n+2}^{i-1})$$

It is similar to the backoff, basically, the probability of a trigram model is its trigram probability minus a fixed discount if this trigram word exists and then plus a factor times its bigram probability. The bigram probability is also calculated in this way by its unigram probability.

The sum of the factors should be 1. So, another function for the factor is:

$$1 - \lambda_{w_{i-n+1}^{i-1}} = \frac{\delta}{\sum_{w_i} c(w_{i-n+1}^i)} N_{1+(w_{i-n+1}^{i-1} \bullet)}$$

It seems that the performance of this method is not better than other smoothing models. I think the reason is that the database is too small. I found that the probability calculates by each model is extremely small. This method uses a more accurate will to split probability, sometimes, although the probability of one sentence is not 0, it is too small for Java to represent, Java would just regard it as 0. In this case, the perplexity would also be infinity. In my opinion, if the database is larger, this method would perform better.

References

[1] Bill MacCartney, NLP Lunch Tutorial: Smoothing,

<https://nlp.stanford.edu/~wcmac/papers/20050421-smoothing-tutorial.pdf>

[2] Kneser-Ney smoothing explained,

<http://www.foldl.me/2014/kneser-ney-smoothing/>

Attachments

- The perplexity of each sentences based on each model:

1-gram model:

perplexity of the 1 sentence: 57.15344321060777

perplexity of the 2 sentence: 25.788648872023693

perplexity of the 3 sentence: 23.66429629654526

perplexity of the 4 sentence: 23.12516172069418

perplexity of the 5 sentence: 20.943823275701618

perplexity of the 6 sentence: 22.117633680233954

perplexity of the 7 sentence: 21.040943042048998

perplexity of the 8 sentence: 25.3565953872636

perplexity of the 9 sentence: 20.58141877420034

perplexity of the 10 sentence: 25.062354245529253

perplexity of the 11 sentence: 20.183717488614157

perplexity of the 12 sentence: 18.605219449906528

perplexity of the 13 sentence: 27.5815414073941
perplexity of the 14 sentence: 21.815531643715687
perplexity of the 15 sentence: 21.280022691213098
perplexity of the 16 sentence: 22.069953370841482
perplexity of the 17 sentence: 23.1470870238554
perplexity of the 18 sentence: 21.839488276338447
perplexity of the 19 sentence: 19.550696255772884
perplexity of the 20 sentence: 24.32565965823354
perplexity of the 21 sentence: 19.763901363170792
perplexity of the 22 sentence: 20.70955167950954
perplexity of the 23 sentence: 21.59688256287937
perplexity of the 24 sentence: 23.65845172482019
perplexity of the 25 sentence: 21.88260653621519
perplexity of the 26 sentence: 21.233721956046708
perplexity of the 27 sentence: 18.373680124108546
perplexity of the 28 sentence: 21.518220654777437
perplexity of the 29 sentence: Infinity
perplexity of the 30 sentence: 21.987845601316632
perplexity of the 31 sentence: 26.06113105380861
perplexity of the 32 sentence: 21.945851610612603
perplexity of the 33 sentence: 23.03659030419576
perplexity of the 34 sentence: 21.65221547641508
perplexity of the 35 sentence: 21.65353892007013
perplexity of the 36 sentence: 22.007635372975976
perplexity of the 37 sentence: 20.2716425131026
perplexity of the 38 sentence: 27.732406235946897
perplexity of the 39 sentence: 23.271623808268146
perplexity of the 40 sentence: Infinity

perplexity of the 41 sentence: 24.079694417794077
perplexity of the 42 sentence: 22.29467194546564
perplexity of the 43 sentence: 22.976551038748962
perplexity of the 44 sentence: 22.13545448777216
perplexity of the 45 sentence: 36.786519858069546
perplexity of the 46 sentence: 25.69308760022841
perplexity of the 47 sentence: 23.6029562309208
perplexity of the 48 sentence: 26.238325000895415
perplexity of the 49 sentence: 19.89016276775483
perplexity of the 50 sentence: 20.33191744455163
perplexity of the 51 sentence: 22.75553911088225
perplexity of the 52 sentence: 20.669380315565355
perplexity of the 53 sentence: Infinity
perplexity of the 54 sentence: Infinity
perplexity of the 55 sentence: 21.844596784535028
perplexity of the 56 sentence: 20.145060711255162
perplexity of the 57 sentence: 21.204815591021514
perplexity of the 58 sentence: 21.772202779823868
perplexity of the 59 sentence: 21.854142009509783
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perplexity of the 61 sentence: 18.751029048227736
perplexity of the 62 sentence: 21.834536391915893
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perplexity of the 64 sentence: 39.47360262874969
perplexity of the 65 sentence: 24.299483783308656
perplexity of the 66 sentence: 19.66286798813818
perplexity of the 67 sentence: 21.73390143648852
perplexity of the 68 sentence: 20.473525616789335

perplexity of the 69 sentence: 19.224626610253107
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perplexity of the 72 sentence: 21.038415765368377
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perplexity of the 93 sentence: 18.049140090947887
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perplexity of the 95 sentence: 25.389911732338245
perplexity of the 96 sentence: 20.801366792903117

perplexity of the 97 sentence: 19.344866464906943

perplexity of the 98 sentence: 21.323074855665222

perplexity of the 99 sentence: 19.15674268014687

perplexity of the 100 sentence: 17.11081566856208

This article is English

1gram perplexity: Infinity

2-gram model:

perplexity of the 1 sentence: Infinity

perplexity of the 2 sentence: Infinity

perplexity of the 3 sentence: 10.94608026186634

perplexity of the 4 sentence: Infinity

perplexity of the 5 sentence: Infinity

perplexity of the 6 sentence: 10.91744315746754

perplexity of the 7 sentence: Infinity

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perplexity of the 12 sentence: 9.98584556255997

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perplexity of the 14 sentence: 11.38738489722748

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perplexity of the 97 sentence: 12.538474060170614
perplexity of the 98 sentence: Infinity
perplexity of the 99 sentence: 8.94100938832774
perplexity of the 100 sentence: 10.118730412077541

This article is English

2gram perplexity: Infinity

3-gram model:

perplexity of the 1 sentence: Infinity

perplexity of the 2 sentence: Infinity

perplexity of the 3 sentence: Infinity
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perplexity of the 69 sentence: 9.19792033548874
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perplexity of the 83 sentence: 7.777356014506672
perplexity of the 84 sentence: 6.861387017529511
perplexity of the 85 sentence: Infinity
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perplexity of the 100 sentence: Infinity

This article is English

3gram perplexity: Infinity

Laplace smoothing trigram model:

perplexity of the 1 sentence: 41.035842265908656
perplexity of the 2 sentence: 12.72547183036997
perplexity of the 3 sentence: 10.667942073062557
perplexity of the 4 sentence: 12.039216144095581
perplexity of the 5 sentence: 12.60367996687024
perplexity of the 6 sentence: 10.553182232635763
perplexity of the 7 sentence: 12.032907680443339
perplexity of the 8 sentence: 13.098267552502701
perplexity of the 9 sentence: 10.339714321084728
perplexity of the 10 sentence: 9.505237086482547
perplexity of the 11 sentence: 9.574419970479166

perplexity of the 12 sentence: 7.478293021440006
perplexity of the 13 sentence: 20.732634307683714
perplexity of the 14 sentence: 9.271004951637659
perplexity of the 15 sentence: 9.210089376325522
perplexity of the 16 sentence: 13.539225417617814
perplexity of the 17 sentence: 9.192283234082403
perplexity of the 18 sentence: 9.002655917509816
perplexity of the 19 sentence: 9.69312369212302
perplexity of the 20 sentence: 10.244291419320797
perplexity of the 21 sentence: 9.700581193078998
perplexity of the 22 sentence: 8.935055174701533
perplexity of the 23 sentence: 10.5206136959501
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This article is English

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This article is English

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This article is English

Linear interpolation trigram perplexity: 11.117518958431667

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This article is English

Absolute discount smoothing trigram perplexity: 10.750563197451966

● The result of "th*" probability:

vocabulary, trigram, LaPlace trigram, backoff trigram, linear interpolation trigram, absolute discount trigram

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