

# ANLP 2024 Assignment 1

due: Thursday, 17th October, 12pm (noon), via Gradescope (see section 3)

## 1 Overview of task, motivation, and goals

### What will you do?

In this assignment, you will use language modeling to detect what language a document is written in. Specifically, you will write Python code to do the following:

- build a trigram language model over characters (not words!): read in a text file, collect counts for all character 3-grams, estimate probabilities, and write out the model to a file.
- generate random output according to a similar model provided by us (which you'll need to read in from a file).
- read in a test document and compute its perplexity according to one of these models.

You'll also need to write a short description of what you did and why, and answer some questions.

### Why?

By completing this assignment, you will practice skills that are important for doing NLP, and for other research in Informatics. This assignment will allow you to demonstrate that you:

- understand some of the concepts and issues involved in language modeling and working with real language data;
- can implement a basic Python program; and
- have some of the skills needed to write a good scientific report. These include being able to clearly explain/justify decisions you have made, describe results you have obtained, and draw appropriate conclusions from them. We don't just care that you got the right answer, we also care that you are able to explain how and provide evidence justifying your answer.

## 2 Working with others (and not)

The assignments for this class are intended to be done in *pairs*: by working with another student, you can discuss ideas and work things out together. If you have not specified a preferred partner, we will try to match you with a partner with a different skill set to your own, although this may not be possible in all cases. If, instead, you have chosen your own partner, you will have to work with a different partner for the next assignment.

You may discuss any aspects of the assignment with your partner and divide up the tasks however you wish; but we encourage you to collaborate on each part rather than doing a strict division of tasks, as this will enable better learning for both of you.

Both members of your pair will receive the same mark and you are both responsible for the work, so make sure you have agreed on the final submission before submitting it.

You may also discuss high-level concepts and general programming questions with others in the class; but you may **not** share your specific solutions, answers or code directly with other groups. Your code and report must be your own group's work. Important points include (but are not limited to) the following:

- **Any key ideas from outside sources should be appropriately cited**, and direct quotes must use quotation marks. If you re-use code snippets from outside sources, these should also be clearly marked and the source cited.
- **Be careful when using Piazza; if in doubt, make your post private.** Questions about the assignment can sometimes give away parts of the solution to other students. If you're not sure, use a private post and the instructors will make it public if appropriate.
- **You must take reasonable measures to protect your assessed work from unauthorised access.** For example, you may not store or post your work anywhere in a way that could be accessed by other students (except your partner).

See the School's guidance on academic misconduct for more details:

<http://web.inf.ed.ac.uk/infweb/admin/policies/academic-misconduct>

## 3 Submitting your assignment

### 3.1 How and what to submit

You will submit your assignment through a service called Gradescope, via Learn. See Learn for detailed instructions on how to submit using Gradescope.

Your pair should submit a single .pdf file. Please use either the .tex or .docx template provided on the Opencourse website, in which you will fill in:

- Your solutions to each of the tasks. Each answer should start on a new page, as in the template, to help with marking. (That doesn't mean each answer should take the whole page; many answers will be much shorter.)
- Your code for tasks 1-5, in the Appendix section of the .pdf. We will mainly mark based on your written answers in the report, but may need to refer to the code in some cases.

### 3.2 Extensions and late submissions

Unfortunately, no extensions are allowed, following the University recommended policy.

Late submissions will be penalized.

## 4 Assignment specification

### 4.1 Data

The data we use for this project is part of the Europarl corpus, which requires a license to use. The University has a license, so **to get the data you must be inside the University intranet**: either by using a machine in a University lab or via the University VPN. You may use the data for your University work but may not distribute it to others.

From a University machine (e.g. in the DICE labs) or VPN, the data is available at <http://www.inf.ed.ac.uk/teaching/courses/anlp/data/assignment1-data.tgz> (copy-paste the link in your browser if clicking on it fails to download the file).

Download and unzip the data (e.g. using Archive Manager on DICE). It will consist of:

- **training.en** - English training data
- **training.es** - Spanish training data
- **training.de** - German training data
- **model-br.en** - a pre-trained language model file
- **test** - test document

### 4.2 Code

To help students who are new to programming, we've provided a very small amount of code that may help you get started with the tasks specified below. The code is available here.

You are not required to use the provided code, and if you are an experienced programmer you may prefer not to.

For this assignment, you must implement the solutions yourself, and should not use existing language modelling toolkits. You may use other support code provided you cite the source.

### 4.3 Tasks

#### ✓ Warmup exercise (0 marks)

This task is not worth any marks, but you should make sure you have completed it correctly before proceeding. Since it is not part of the final mark, feel free to discuss with other students.

Before starting to code, you should always have an idea of what your program's expected output should be, so you can check that your implementation is correct. In the last part of this assignment, you'll be asked to compute the perplexity of some real language data under a language model that's also computed from real data. But to test your code, you'll want (at least!) a simple test case that you've done by hand.

Consider the following trigram character language model, where  $\#$  is a symbol used to mark both the start and end of a sequence, and probabilities are written as  $p(c_i | c_{i-2}, c_{i-1})$ . So,  $p(\mathbf{a} | \# \mathbf{b})$  means the probability of the character  $\mathbf{a}$  given that the immediately preceding character is  $\mathbf{b}$  and the one before that is  $\#$ .

$p(\mathbf{a}   \#\#) = 0.2$	$p(\mathbf{b}   \#\#) = 0.8$	$p(\#   \#\#) = 0.0$
$p(\mathbf{a}   \#\mathbf{a}) = 0.2$	$p(\mathbf{b}   \#\mathbf{a}) = 0.7$	$p(\#   \#\mathbf{a}) = 0.1$
$p(\mathbf{a}   \#\mathbf{b}) = 0.15$	$p(\mathbf{b}   \#\mathbf{b}) = 0.75$	$p(\#   \#\mathbf{b}) = 0.1$
$p(\mathbf{a}   \mathbf{a}\mathbf{a}) = 0.4$	$p(\mathbf{b}   \mathbf{a}\mathbf{a}) = 0.5$	$p(\#   \mathbf{a}\mathbf{a}) = 0.1$
$p(\mathbf{a}   \mathbf{a}\mathbf{b}) = 0.6$	$p(\mathbf{b}   \mathbf{a}\mathbf{b}) = 0.3$	$p(\#   \mathbf{a}\mathbf{b}) = 0.1$
$p(\mathbf{a}   \mathbf{b}\mathbf{a}) = 0.25$	$p(\mathbf{b}   \mathbf{b}\mathbf{a}) = 0.65$	$p(\#   \mathbf{b}\mathbf{a}) = 0.1$
$p(\mathbf{a}   \mathbf{b}\mathbf{b}) = 0.5$	$p(\mathbf{b}   \mathbf{b}\mathbf{b}) = 0.4$	$p(\#   \mathbf{b}\mathbf{b}) = 0.1$

What is the perplexity of the sequence  $\#\# \mathbf{abaab} \#$  under this model? (You don't need to add anything to the report for this warmup exercise.)



#### 4.3.1 Preprocessing each line (10 marks)

For the datasets we gave you, the language identification task is too easy if we include the entire character set, because there are some characters that only occur in one of the languages. So, we ask you to preprocess the data to make things a bit more interesting.

Write a function or method called `preprocess_line` that takes a line of text (string) as an argument. It should return a new string which removes all characters from the line that are not in the following set: characters in the English alphabet, space, digits, or the `'.'` character. (That is, remove characters with accents and umlauts and the other punctuation marks). Your function should also lowercase all remaining characters and convert all digits to `'0'`.

In the remainder of your program, you should treat each line as a separate sequence for modelling purposes (rather than treating the entire input file as a single sequence).

Depending on how you write the rest of your program, you may do slightly more in this function than just what we have specified. If so, add a comment to your code explaining what else you did and why. You do *not* need to justify the steps we explicitly asked for.

You should use this function in building your language model and scoring the test document; i.e., your language model should be over n-grams of lowercase letters plus a few other characters as noted.

To get credit for this task, include the code for this function in your report.



#### 4.3.2 Examining a pre-trained model (10 marks)

We have provided a pre-trained language model in the file `model-br.en`. This model was trained on a corpus of English, but not necessarily the same one we gave you.

Each line of this file lists three characters followed by a tab and a number. The number represents the model's estimated probability of the third character given the previous two. For example, one of the lines looks like this (where `<tab>` is a tab character):

```
and<tab>2.507e-01
```

which means that for this model,  $\hat{p}(d|a, n) = 0.2507$ . The file is alphabetical, so at the beginning you will see a lot of trigrams that include spaces and punctuation characters.

By looking at the language model probabilities in this file, can you say anything about the kind of estimation method that was used? We are not asking for certainty, but based on your knowledge of English and of different estimation methods, you should be able to narrow down the possibilities.

Write a paragraph or so explaining which method(s) might have been used, and say what evidence your guess is based on.

*Note:* We designed our LM file for simplicity, not space efficiency. Real LM files are far more compact but far harder to read!

### 4.3.3 Implementing a model: description and example probabilities (35 marks)

Now write code to build your own trigram character language model. You will need to read in a training file, collect counts, estimate probabilities, and write the model probabilities into a file.

In your report, describe the method you used to estimate the probabilities, and briefly justify why you used that method. Your description should include, but not be limited to, an equation. You should also explain any simplifying assumptions you have made. Please see the Marking Guide below for hints about what is considered a good explanation; most pairs should only need 1-2 paragraphs here. Your report need **not** describe how you implemented the method in your code, but please do include comments in the code itself indicating what you did.

Also include in your answer an excerpt of the language model for English, displaying all n-grams with the two-character history  $n\ g$  and their probabilities. Explain what you would expect to find and why. Do the results match your expectations?

*Hint 1:* In deciding on an estimation method, consider what you will need to do in the rest of the assignment, and make sure your method will work for what you need to do. You can do well on this question by implementing a simple method, as long as it works for the other tasks you will need to do (see also Section 5).

*Hint 2:* Consider what kinds of data structures will be useful for storing your counts and probabilities. For example, you might want to use a dictionary with an entry for each possible history, where the value stored is the distribution over next characters given that history. (You'll then need to decide what kind of structure that distribution is!)

## Use sampling improvements

### ✓ 4.3.4 Generating from models (15 marks)

Write a function or method called `generate_from_LM` that uses a language model to generate random output sequences. That is, the sequences should be generated according to the probabilities in the language model.

Using this code, generate 300 characters of random output for each of two different models: (a) the model you estimated from the English training data, and (b) the model in `model-br.en` (you will need to write code to read the model in from the file).

In your report, include the output from each model and explain briefly what your code does to generate a sequence given an LM. Your explanation could be in English or pseudocode, but should be clear and concise. Also comment *briefly* (max 1 paragraph) on any differences you see between the two sequences you generated, and what seems likely to have caused them.

*Hint:* You can do most of this question before you have implemented your own model.

### ✓ 4.3.5 Computing perplexity (15 marks)

Extend your program to read in a test document and compute (and output) its perplexity under the estimated language models.

What is the perplexity of the test document we provided under each of the three language models you estimated from the training documents? How can you use these numbers to guess the language of the test document without looking at it?

Suppose we ran your program on a new test document and told you the perplexity under your English LM. Would this be enough for you to determine if the document is written in English? Why or why not?

*Hint:* How will you know if you've implemented perplexity correctly? First, consider what is a reasonable value to expect (look back over the LM evaluation slides as a starting point). Second, consider how to test your code. One way would be to create a test file with the LM from Question 4.3, read it in, and use it to compare your program's perplexity result to your hand computation from Question 4.3. However, a single test case is rarely enough. Think carefully about other tests you could use.

### 4.3.6 Extra question (15 marks)

Devise a further question you would like to explore and extend your work in order to address that question. Explain briefly what the question was, how you addressed it, and what results you got.

As noted in the marking guidelines (below), if you do a good job up to question 4.3.5, with only minor errors, you will still be getting an A. This question should be considered **extra**, beyond what is expected of most students. The time it takes to answer this question is not proportional to how many extra marks you'll get, though it will help you learn more, **if** you already fully

understand the previous parts. Also, just implementing a more complicated method is unlikely to gain you many marks. We are really looking for evidence here that you have thought about the issues involved in language modelling and come up with an interesting question based on that.

**WARNING:** you will only get credit for this part if your basic method is correct and clearly explained. This question is intended to challenge students who already feel solid on the basic material in the course, and want to go further. **Do not** attempt this question unless you have completed all the previous questions, and are sure that you've done a good job on those. Also, **do not** attempt this question if you have personally spent 12 or more hours on the assignment already. On similarly structured assignments in previous years, we've rarely (if ever) awarded more than 8 marks on the last part, or less than 1% of your overall course mark. Unless you really whizzed through the earlier questions, please stop now and spend your time and energy revising other course materials or getting more sleep. Both are likely to have a much bigger impact on your final mark.

## 5 Marking and how to do well

### 5.1 The British marking scale

Assignments will be marked on the usual British scale:

Numeric mark	Equivalent letter grade	Approximate meaning
< 40	F	fail
40-49	D	sufficient for Diploma
50-59	C	good; sufficient for MSc
60-69	B	very good
70-79	A3	excellent/distinction
80-100	A1, A2	outstanding/high distinction

Please note typical specifications for marks above 70 across the University:

**A1 90-100** Often faultless. The work is well beyond what is expected for the level of study.

**A2 80-89** A truly professional piece of scholarship, often with an absence of errors.

As ‘A3’ but shows (depending upon the item of assessment): significant personal insight / creativity / originality and / or extra depth and academic maturity in the elements of assessment.

#### **A3 70-79**

Knowledge: Comprehensive range of up-to-date material handled in a professional way.

Understanding/handling of key concepts: Shows a command of the subject and current theory.

Focus on the subject: Clear and analytical; fully explores the subject.

Critical analysis and discussion: Shows evidence of serious thought in critically evaluating and integrating the evidenced and ideas. Deals confidently with the complexities and subtleties of the arguments. Shows elements of personal insight / creativity / originality.

Structure: Clear and coherent showing logical, ordered thought.

Presentation: Clear and professional with few, relatively minor flaws. Accurate referencing.

Figures and tables well constructed and accurate. Good standard of spelling and grammar.

### 5.2 What are we looking for?

Write your answers to each question separately (with question number) in your report. Different people will mark different parts, so please try to make each answer stand alone. If need be you can refer back or forward to your answers to other questions, but try to keep answers as self-contained as possible.

To do well on this assignment (70-79), focus on doing the following:

- Complete up to task 4.3.5 and provide working solutions, even if they are simple. You can mention in 1-2 sentences if you think there is a better solution and why, but you will not get extra marks for a detailed explanation of a complex method you did not implement.



- Answer the questions correctly, clearly and concisely.
- Include brief but clear comments in your code indicating what each function does, including what its arguments and return values are. See the comments inside triple quotes in the lab code for examples—you do not need to comment nearly every line as we did, but a few well-placed comments explaining what each block is doing can be useful.
- Describe the results of your work, not a history of it. So, avoid descriptions like this one:

“We implemented [Method 1], which is formulated as [equation], because [reason]. [Considerably more explanation of Method 1 here]. However, we then realized that [Method 1] wouldn’t work [reasons here], so instead we ended up using [Method 2]. [Explanation of Method 2].”

This is not appropriate style for a scientific report, and it is confusing. The reader initially thinks you used one method, but then later discovers you actually did something else. The reader (whether a marker reading your assignment or a scientist reading a research paper) does not want to know the history of your ideas. The reader wants to know what you actually ended up doing, and why. The above explanation should be rewritten as follows:

“We used [Method 2] to implement probability estimation in this assignment, because [Method 1] does not work [reasons here], and [other reasons for using Method 2]. [Explanation of Method 2].”

- Explain the terms in your equations, and say what they mean within the context of this report (if appropriate, give actual values). When you are doing an assignment, this shows the marker that you actually understand the equation yourself. When you are writing a longer paper or thesis, in many cases the reader will not actually know ahead of time what the terms in your equations mean so explaining them also helps the reader understand.
- Unless you are explicitly asked to, do not include code in the answers to each question—code should go in the appendix, and it’s usually a bad sign if the marker needs to look at it to understand what you did. Also avoid detailed explanations of *how* you implemented things (in terms of data structures, iteration, etc). Focus on *what* you implemented (what does your code do) and *why*. You should demonstrate that you understand the conceptual issues, have done something reasonable where there are choices involved, and can justify why your choices are reasonable. You may also have some arbitrary or trivial choices to make, and in this case it is probably not worth mentioning those in the report. Honing your judgment about what is important and what isn’t is an important academic skill and this is a good chance to start working on it.

We will **not** be assigning any marks based on the quality or style of your code (provided it works), since many students are still just learning. However we do insist that you include your code (a) to discourage plagiarism, and (b) since it may help us provide useful feedback.