Catching Plagiarists

This homework presents a real problem that requires a software solution. Your goal is to try to quickly determine the similarities between documents in a large set to see if you can detect plagiarism.

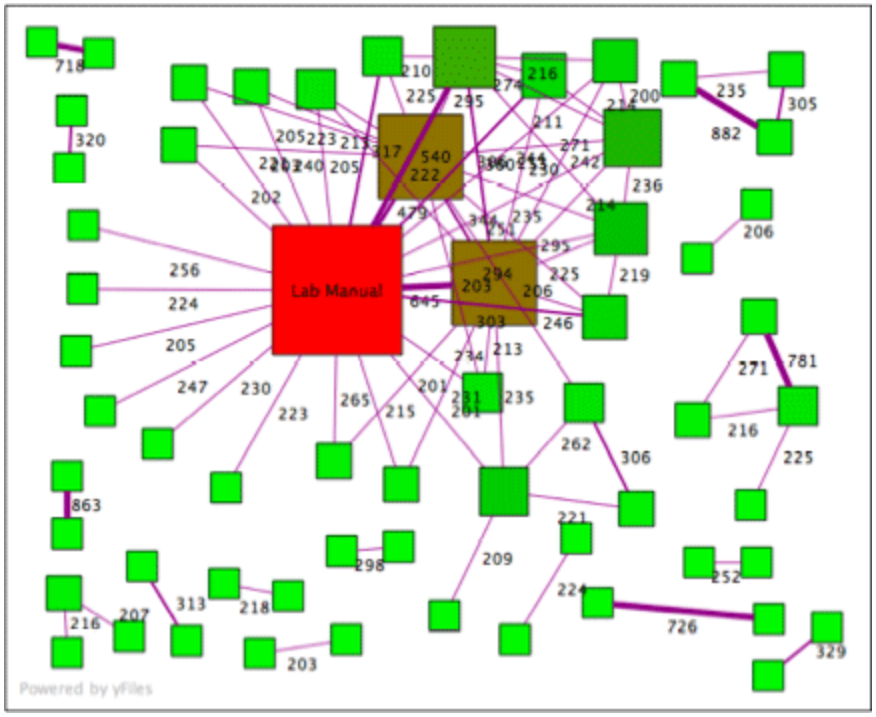
> Topics: File I/O, Java Collections, Iterators, Algorithm Efficiency, Testing

> Due Date: February 07 @ 11:59PM

Starter Files Here& README Template Here

Background

Below is an actual graph of lab reports submitted for an introductory Physics course at a large university. This graph represents a portion of data collected for about 800 lab reports. In the graph, each node represents a lab report and each edge indicates the number of 6-word phrases shared between two documents. To reduce visual clutter, a threshold of 200 common phrases has been set, so a document sharing fewer than 200 6-word phrases with all other documents is not shown. The “Lab Manual” is a style-guide for the lab report and the two brown boxes are sample lab reports that were distributed; as you can see, many students apparently “borrowed liberally” from these help materials. Particularly suspicious are clusters like the one in the top-right corner: those documents have an inordinate number of 6-word phrases in common with each other. It is likely those people turned in essentially the same lab report or copied large portions from each other.



In order to detect likely cases of plagiarism, you will find the common word sequences among a closed set of documents. Your **input** will be a set of plain-text documents and a number `n`; your output will be a representation showing the number of sequences of `n` words (called **n-grams**) that each document has in common with every other document in the set. Using this representation, you will identify suspicious groups of documents that share many common n-grams among themselves but **not** with others.

Output

We could first think of our intended output as a \(D \times D\) matrix, where \(D\) is the total number of documents. Each cell of the matrix will represent the number of shared n-grams between the corresponding pair of documents:

	A	B	C	D	E
A	-	4	50	700	0
B	-	-	0	0	5
C	-	-	-	50	0
D	-	-	-	-	0
E	-	-	-	-	-

From this table, we can conclude that the writers of documents A, C and D share a high number of similar 6-word phrases. We can be fairly certain that A and D collaborated on this assignment. However, printing and storing a $D \times D$ matrix is unmanageable for large sets: look at how many wasted spaces we have for $D = 5$! **You should instead produce a list of documents ordered by number of "hits".** For example:

```
700:    A, D
50:     A, C
50:     C, D
5:      B, E
4:      A, B
```

We've gone from 25 entries to 5 without losing any information! For even larger sets of documents, it may be important to only report document pairs with a high number of shared n-grams above a certain threshold.

The Documents

We will provide you with different folders of documents that represent the sets. One set will be small (~25 documents); its size will allow you to calculate expected values for unit tests using this set. The other sets will be larger: one has 75 documents and the other has over 1300 documents (the documents came from www.freeessays.cc, a repository of *really bad* high school and middle school essays on a variety of topics).

Strategy Discussion

For this discussion, we'll assume that we have w distinct n-grams across all of our documents. The straightforward matrix solution, requiring us to compare each n-gram in a document to all other n-grams in all other documents, has an $O(w^2)$ time complexity. This is polynomial time: fast in some contexts, but the growth will be prohibitive here. For example, if the 25 document set takes 10 seconds to process, the 1300 document set will take several minutes—provided that you can store the matrix representation in memory!

We'll need to improve on this initial strategy in terms of both time and space complexity. The use of hash tables will allow us to speed up the computation dramatically, but for large numbers of documents, we'll still run out of program memory. Our solution will be to create supplementary data files that we can store on/load from the disk as needed.

Assignment Steps

Part 0: Read and Understand the Requirements

Understanding the problem is the first step to solving it. Take time to read through this writeup and the provided interfaces/files completely before starting. Make sure you fully understand the assignment before you try to code anything.

Testing is an essential part of every coding assignment and we expect you to test your code thoroughly. You are only required to test the `DocumentsProcessor.java` file for this assignment. To receive full credit, 80% code coverage must be obtained. Name your testing file `DocumentsProcessorTest.java`. Failure to submit a test class with this name that compiles will result in a grade of zero for the assignment.

Part 1: Processing the Documents

> **FILES:** `DocumentIterator.java`, `DocumentsProcessor.java`

For this part, you will first modify the provided `DocumentIterator.java` and then use it to implement the method `processDocuments()`, defined in the `IDocumentsProcessor.java` interface.

We require that you use an `Iterator` to iterate through the contents of each of the text documents to identify the n-grams. To do this, modify the `DocumentIterator.java` constructor so that it takes in a `Reader` and a value `n` in that order. Then, modify the `next()` method so that it yields an `n`-gram. You should ignore non-letter character and convert all Strings to lowercase. As provided, the `DocumentIterator.java` gives you a model of how to iterate over the `1`-grams of a document. You may be tempted to use the `Reader`'s `mark()` and `reset()` to read the n-grams, but you should consider whether it might be simpler to use an auxillary data structure instead.

> **UNDERSTANDING N-GRAMS**
> Suppose, for example a document contains the sentence `"This hw is about catching plagiarists"` and we choose `n = 4`. To save space, we should eliminate concatenate the words in each n-gram. The appropriate n-grams would be:
>
> `["thishwisabout", "hwisaboutcatching", "isaboutcatchingplagiarists"]`

The function `processDocuments()` processes a set of documents in a director using your `DocumentIterator`. The `directoryPath` input represents the path to the respective directory of files, and `n` represents the number of words in our n-grams. The `Map` (output) associates each document (its name) to a list containing its n-grams.

EXAMPLE FOR `processDocuments()`

if a folder/directory “test_files” contains two text files:

`file1.txt: “This is a file.”`

`file2.txt: “This is another file.”`

Calling `processDocuments("test_files", 2)` should return a Map with contents:

`{"file1.txt"=["thisis", "isa", "afile"], "file2.txt"=["thisis", "isanother", "anotherfile"]}`

Part 2: Storing the N-Grams

FILES: `DocumentsProcessor.java`

Now, implement the `storeNGrams()` method. Your solution will be an example of *indexing*, which is a clever way of storing and retrieving data on demand based on the size of each document in the file. We will return to indexing later on in the course.

This method should create a single file at `ngramFilePath` containing all of the n-grams across all of the documents into that file. Separate the n-grams with spaces. You have access to the n-grams from the input `Map docs`, which is the output of the `processDocuments()` method. In addition to writing to this file (yay, side effects!), you will also return a `List` of `Tuple` objects, each associating the name of the document to its size in bytes. Don’t forget to include the added spaces in the size calculation.

EXAMPLE FOR `storeNGrams()`

if a folder “test_files” contains two text files:

`file1.txt: "This is a test document."`

`file2.txt: "This is also a test document."`

Calling `storeNGrams(docs, 4)` should return a `List` with contents:

`[("file1.txt", 28), ("file2.txt", 42)]`

Part 3: Similarity Objects and Computing Similarities

FILES: `DocumentsProcessor.java`, `Similarities.java`

The `Similarities` object encapsulates two documents (identified by their filenames) and a count of the n-grams they have in common. So that we can determine which pairs of documents are the most similar, we have that `Similarities implements Comparable<Similarities>`. This means that you will need to implement the `compareTo()` method for `Similarities`. Think: which field(s) should you use to compare two `Similarities`?

Next, implement `computeSimilarities()`: this method will take the file path of the n-gram file and the index list (both created by `storeNGrams()`) as inputs and return a `TreeSet<Similarities>`. When creating this `TreeSet`, make sure that you traverse the n-gram file just once: this will help you avoid exponential runtimes and losing points!

WHY TREESETS?

The `TreeSet` data structure is ordered, making it convenient to find the most similar document pairs in the completed structure. Inserting into a `TreeSet` is a bit slower than inserting into a `HashSet`, but there is a significant speedup when trying to find the top/bottom values in the Tree implementation. A `TreeSet` requires that its entries implement the `Comparable` interface in order to make this possible.

Here is a broad outline for how to build your `TreeSet`:

- If an n-gram is found in two documents and the corresponding `Similarities` object is not yet in the set, create that object and then add it to the set.
- Otherwise, if those two documents already had a corresponding `Similarities` object in the set, then find it and increment its count.

This will help you to build an **exhaustive** `TreeSet`, where any pair of documents with at least one n-gram in common is present in the Set but no pair is present more than once.

You might find it necessary to use additional data structures when implementing `computeSimilarities()`. These data structures should be kept local (not stored as instance variables) and you should be mindful of the runtimes of the operations for the structures that you choose.

EXAMPLE FOR `computeSimilarities()`

If a folder “test_files” contains three text files:

```
file1.txt: "No one can copy from me. You can try if you want to"
```

`file2.txt: "One can copy from me. I will try to copy others."`

`file3.txt: "To copy others is my hobby. I can copy from anyone. You want to can copy from me as well?"`

Calling `computeSimilarities()` based on trigrams should return a `TreeSet` containing three Similarities objects:

`[{file1="test2.txt", file2="test3.txt", count=3}, {file1="test1.txt", file2="test3.txt", count=3}, {file1="test1.txt", file2="test2.txt", count=3}]`

Part 4: Print Similarities

FILES: `DocumentsProcessor.java`, `Similarities.java`

Next, implement the `printSimilarities()` method, which takes the `TreeSet` of `Similarities` objects returned by `computeSimilarities()` and a similarity threshold number and prints all pairs of documents that have a number of shared n-grams exceeding the threshold. Print this list of document pairs in descending order; in order to do this, you may need to create a new `Comparator<Similarities>` in order to do so.

> You can review Comparators here.

Part 5: Improved Performance

The approach that we've outlined in Parts 0-4 already solves our problem: given a set of documents, we can find all of the document pairs that have the most overlap. There is a problem, though: this approach requires us to store a `Map` in program memory containing all n-grams in all of the documents. For a large document set, this will not be feasible!

We will refactor our code by merging the `processDocuments()` and `storeNGrams()` methods. This new method, called `processAndStore()`, has the following signature:

```
List<Tuple<String, Integer>> processAndStore(String directoryPath,
                                             String sequenceFile,
                                             int n);
```

This method will take the path to the document folder, the path to the output file, and the size of the n-grams as input. You will *not* create a `Map` containing all n-grams; instead, you will store all the n-

grams directly into the n-grams file, reducing demands on program memory (RAM) dramatically. This method will return the `List` of tuples of files and their sizes in the sequence file.

Part 6: Submit to Gradescope

Submit all of your classes (DocumentIterator.java, DocumentsProcessor.java, DocumentsProcessorTest.java, Similarities.java, Tuple.java), the `readme.txt` file, and all relevant testing files to Gradescope.

> **SUBMITTING TESTING FILES**
> To submit any directories that you build for your own test cases, make sure to read the following carefully. First, place these directories directly in the same place that your source code lives. Second, make sure that the directories use relative paths (e.g. `my_tests` instead of `/Users/sharry/Documents/hw1/my_tests`). Finally, when you go to submit, please zip each of the directories up independently. Ask in OH if you need help with this.

Make sure that you follow all of the CIT 5940 testing guidelines so that the autograder runs properly on your submission. Submissions without a test class will result in a grade of zero on the assignment.

- Achieve high code coverage
- Write unit tests for everything
  - Prefer many unit tests with just one or two assertions
  - Some longer tests with many assertions may be appropriate, but these aren't as useful for debugging
- Submit all files required for testing, including any text or data files you may have generated.

Don't forget to polish, comment, and take pride in your code! You worked hard to finish this assignment, so make sure that the presentation of your code reflects that.

> **STYLE CHECKING HERE IS A LINK TO INSTRUCTIONS FOR INSTALLING AN AUTOMATED STYLE CHECKER FOR ECLIPSE AND FOR INTELLIJ. THIS STYLE CHECKER USES EXACTLY THE SAME GUIDELINES THAT YOU'LL BE GRADED ON; THAT IS, IF YOU PASS THESE STYLE CHECKS IN YOUR IDE, YOU'LL GET FULL CREDIT ON THE STYLE PORTION OF YOUR GRADE!**

Grading

Your grade will consist of points you earn for submitting the homework on time and for the final product you submit.

The assignment is worth 205 points.

Description	Points
DocumentsIterator	15
ProcessDocuments	27
Storing n-grams on disk	27
computeSimilarities	27
printSimilarities	15
Performance	24
Commenting, Documentation, and Style	15
Testing	50
Readme	5

Testing is worth a lot of points! Here are a few additional guidelines:

- All test cases must contain an assertion. There will be a flat 10 point penalty if any test is missing an assertion statement.
- All of your tests must pass. Remove failing tests. There will be a flat 10 point penalty if any test fails.
- You will earn full credit for meeting the previous two criteria and achieving at least 80% code coverage.

This assignment was originally developed by Baker Franke and was adapted for Penn by Eric Fouh. This version of the assignment was updated by Harry Smith, 2024.