Lab 5 - Autocomplete

3/14/2025

100 Points Possible

Attempt 1

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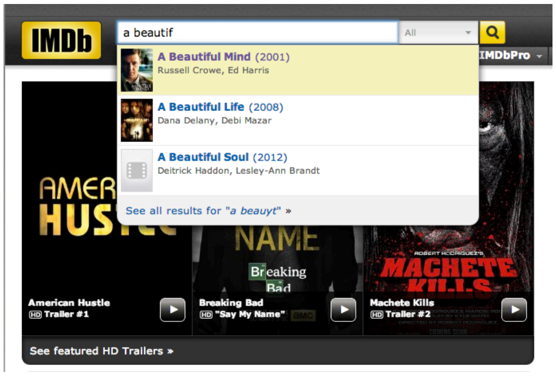
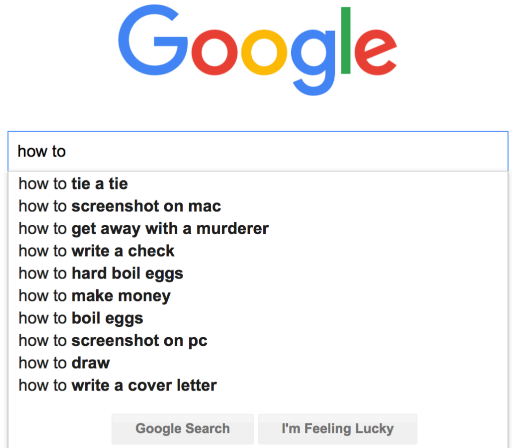
Details

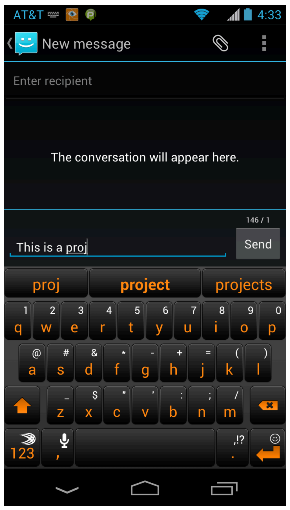
You may find the Autocomplete project zip, containing files referenced below **here (https://canvas.umt.edu/courses/17249/files/1760955/download?wrap=1)** **(https://canvas.umt.edu/courses/17249/files/1760955/download?download_frd=1)** .

Write a program to implement *autocomplete* for a given set of *N terms*, where a term is a query string and an associated nonnegative weight. That is, given a prefix, find all queries that start with the given prefix, in descending order of weight.

Autocomplete is pervasive in modern applications. As the user types, the program predicts the complete *query* (typically a word or phrase) that the user intends to type. Autocomplete is most effective when there are a limited number of likely queries. For example, the **Internet Movie Database (http://www.imdb.com/)** uses it to display the names of movies as the user types; search engines use it to display suggestions as the user enters web search queries; cell phones use it to speed up text input.







In these examples, the application predicts how likely it is that the user is typing each query and presents to the user a list of the top-matching queries, in descending order of weight. These weights are determined by historical data, such as box office revenue for movies, frequencies of search queries from other Google users, or the typing history of a cell phone user. For the purposes of this assignment, you will have access to a set of all possible queries and associated weights (and these queries and weights will not change).

The performance of autocomplete functionality is critical in many systems. For example, consider a search engine that runs an autocomplete application on a server farm. According to one study, the application has only about 50*ms* to return a list of suggestions for it to be useful to the user. Moreover, in principle, it must perform this computation *for every keystroke typed into the search bar* and *for every user*!

In this assignment, you will implement autocomplete by (1) *sorting* the terms by query string; (using one of the sorts introduced in lecture), (2) *binary searching* to find all query strings that start with a given prefix; and (3) *sorting* the matching terms by weight.

Part 1: autocomplete term. Write an immutable data type `Term.java` that represents an autocomplete term: a query string and an associated integer weight. You must implement the following API, which supports comparing terms by three different orders: **lexicographic order (http://docs.oracle.com/javase/7/docs/api/java/lang/String.html#compareTo(java.lang.String))** by query string (the natural order); in descending order by weight (an alternate order); and lexicographic order by query string but using only the first *r* characters (a family of alternate orderings). The last order may seem a bit odd, but you will use it in *Part 3* to find all query strings that start with a given prefix (of length *r*). Term.java, found in the project zip file, contains a stub for this API:

```
public class Term implements Comparable {

    // Initializes a term with the given query string and weight.
```

```
    public Term(String query, long weight)

    // Compares the two terms in descending order by weight.
    public static Comparator byReverseWeightOrder()

    // Compares the two terms in lexicographic order but using only the first r characters of each query.
    public static Comparator byPrefixOrder(int r)

    // Compares the two terms in lexicographic order by query.
    public int compareTo(Term that)

    // Returns a string representation of this term in the following format:
    // the weight, followed by a tab, followed by the query.
    public String toString()

    // unit testing (you should have some Unit Testing here to confirm that your methods work)
    public static void main(String[] args)
}
```

Performance requirements. The string comparison functions should take time proportional to the number of characters needed to resolve the comparison.

A little more guidance: the API includes two static functions (byReverseWeightOrder and byPrefixOrder) that return a Comparator. That just means they return an object that implements the interface Comparator … which just means that object has a “compare” function. For example:

```
public static Comparator byReverseWeightOrder() {
    return new Comparator() {
        public int compare(Term v, Term w) {
            //some condition
                return -1;
            //some condition
                return 1;
            //some condition
                return 0;
            }
        }

    };
}
```

Part 2: binary search. When binary searching a sorted array that contains more than one key equal to the search key, the client may want to know the index of either the *first* or the *last* such key. Accordingly, implement the following API:

> **public class BinarySearchDeluxe {** // Returns the index of the first key in a[] that equals the search key, or -1 if no such key. **public static int firstIndexOf(Key[] a, Key key, Comparator comparator)** // Returns the index of the last key in a[] that equals the search key, or -1 if no such key. **public static int lastIndexOf(Key[] a, Key key, Comparator comparator)** // unit testing (you should have some Unit Testing here to confirm that your methods work) **public static void main(String[] args) }**

Performance requirements. The `firstIndexOf()` and `lastIndexOf()` methods should make at most 1 + $\lceil \log_2 N \rceil$ compares in the worst case, where *N* is the length of the array. In this context, a *compare* is one call to `comparator.compare()`.

Hint: your binary search functions accept a comparator; use this to divide your search space, e.g.:

```
public static  int firstIndexOf(Key[] a, Key key, Comparator comparator) {
    ...
    while (  ... ) {
      ...
      if (comparator.compare( .  ,  .) >= 0 ) // do something
```

```
            else // do something
        }
        ...
    }
```

Hint 2: When a client uses BinarySearchDeluxe, it will have a Term[] array (terms), and a single search Term (searchme) with known length len, and will call the static functions you've written:

first = BinarySearchDeluxe.firstIndexOf(terms, searchme, Term.byPrefixOrder(len));

Part 3: autocomplete. In this part, you will implement a data type that provides autocomplete functionality for a given set of string and weights, using `Term` and `BinarySearchDeluxe`. To do so, *sort* the terms in lexicographic order; use *binary search* to find the all query strings that start with a given prefix; and *sort* the matching terms in descending order by weight. Organize your program by creating an immutable data type `Autocomplete` with the following API:

> **public class Autocomplete {** // Initializes the data structure from the given array of terms. **public Autocomplete(Term[] terms)** // Returns all terms that start with the given prefix, in descending order of weight. **public Term[] allMatches(String prefix) //return an empty array if no matches** // Returns the number of terms that start with the given prefix. **public int numberOfMatches(String prefix) }**

Performance requirements.

- The constructor should make a number of compares that is proportional to $N \log N$ in the worst case, where N is the number of terms. (This is the number of compares required to put the terms in lexicographically sorted order)
- The `allMatches()` method should make a number of compares that is proportional to $\log N + M \log M$ in the worst case, where M is the number of matching terms. ($\log N$ is the number of compares required for a binary search; $M \log M$ is the number of compares required to sort the M matching entries by weight)
- The `numberOfMatches()` method should make a number of compares that is proportional to $\log N$ in the worst case. (It's calling *firstIndexOf* and *lastIndexOf* to get the range, and each is a binary search)
- In this context, a *compare* is one call to any of the `compare()` or `compareTo()` methods defined in `Term`. Any sort must be linearithmic.
- You **may** use `Arrays.sort()` for this assignment. If you wish to use one of the sorts introduced in lecture (e.g. *Insertion.sort*() or *MergeX.sort*()), you may do so. Note that the merge sort implementation is in MergeX.sort; for some reason, Merge.sort doesn't accept Comparators. You may not call any library functions other than those in `java.lang`, `java.util`, `stdlib.jar`, and `algs4.jar`.

Input format. We provide a couple sample input files for testing. Each file consists of an integer N (the number of terms) followed by N pairs of query strings and nonnegative weights. There is one pair per line, with the weight and string separated by a tab. A weight can be any integer between 0 and 2^63 – 1. A query string can be an arbitrary sequence of Unicode characters, including spaces (but not newlines).

- The file **wiktionary.txt (https://canvas.umt.edu/courses/17249/files/1760939/download?wrap=1)** **(https://canvas.umt.edu/courses/17249/files/1760939/download?download_frd=1)** contains the 10,000 most common words in Project Gutenberg, with weights proportional to their frequencies.

- The file **[cities.txt (https://canvas.umt.edu/courses/17249/files/1760946/download?wrap=1)](https://canvas.umt.edu/courses/17249/files/1760946/download?wrap=1)** **(https://canvas.umt.edu/courses/17249/files/1760946/download?download_frd=1)** contains over 90,000 cities, with weights equal to their populations.

```
% more wiktionary.txt
10000
   5627187200   the
   3395006400   of
   2994418400   and
   2595609600   to
   1742063600   in
   1176479700   i
   1107331800   that
   1007824500   was
    879975500   his
                ...
       392323   calves
```

```
% more cities.txt
93827
      14608512  Shanghai, China
      13076300  Buenos Aires, Argentina
      12691836  Mumbai, India
      12294193  Mexico City, Distrito Federal, Mexico
      11624219  Karachi, Pakistan
      11174257  İstanbul, Turkey
      10927986  Delhi, India
      10444527  Manila, Philippines
      10381222  Moscow, Russia
                ...
             2  Al Khāniq, Yemen
```

We have included a sample client (in the form of a unit test at the bottom of Autocomplete.java). It takes the name of an input file and an integer *k* as command-line arguments. It reads the data from the file; then it repeatedly reads autocomplete queries from standard input, and prints out the top *k* matching terms in descending order of weight. This uses your *Term* and *Autocomplete* to perform its work. Use it to verify your code (beyond unit tests).

```
public static void main(String[] args) {

    // read in the terms from a file
    String filename = args[0];
    In in = new In(filename);
    int N = in.readInt();
    Term[] terms = new Term[N];
    for (int i = 0; i < N; i++) {
        long weight = in.readLong();           // read the next weight
        in.readChar();                         // scan past the tab
        String query = in.readLine();          // read the next query
        terms[i] = new Term(query, weight);    // construct the term
    }

    // read in queries from standard input and print out the top k matching terms
    int k = Integer.parseInt(args[1]);
    Autocomplete autocomplete = new Autocomplete(terms);
    while (StdIn.hasNextLine()) {
        String prefix = StdIn.readLine();
        Term[] results = autocomplete.allMatches(prefix);
        for (int i = 0; i < Math.min(k, results.length); i++)
            StdOut.println(results[i]);
    }
}
```

Here are a few sample executions:

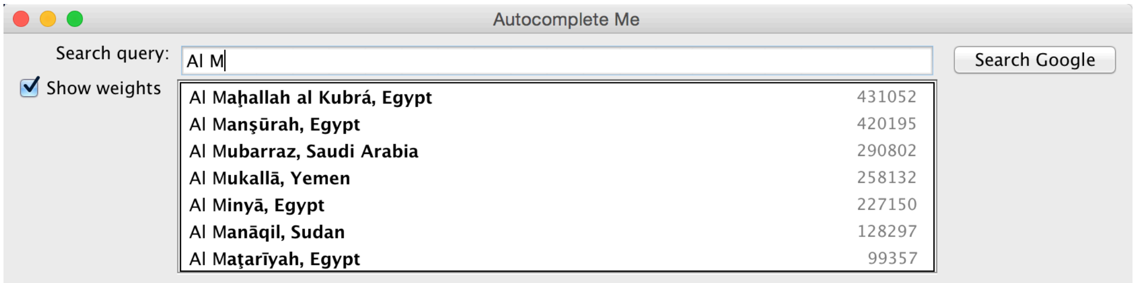
```
% java Autocomplete wiktionary.txt 5
auto
        619695  automobile
        424997  automatic
comp
      13315900  company
       7803980  complete
       6038490  companion
       5205030  completely
       4481770  comply
the
    5627187200  the
     334039800  they
     282026500  their
     250991700  them
     196120000  there
```

```
% java Autocomplete cities.txt 7
M
    12691836  Mumbai, India
    12294193  Mexico City, Distrito Federal, Mexico
    10444527  Manila, Philippines
    10381222  Moscow, Russia
     3730206  Melbourne, Victoria, Australia
     3268513  Montréal, Quebec, Canada
     3255944  Madrid, Spain
Al M
      431052  Al Maḩallah al Kubrá, Egypt
      420195  Al Manşūrah, Egypt
      290802  Al Mubarraz, Saudi Arabia
      258132  Al Mukallā, Yemen
      227150  Al Minyā, Egypt
      128297  Al Manāqil, Sudan
       99357  Al Maţarīyah, Egypt
```

Interactive GUI (optional, but fun and no extra work). We have also included **[AutocompleteGUI.java (https://canvas.umt.edu/courses/17249/files/1760919/download?wrap=1)](https://canvas.umt.edu/courses/17249/files/1760919/download?wrap=1)**

(https://canvas.umt.edu/courses/17249/files/1760919/download?download_frd=1) . The program takes the name of a file and an integer *k* as command-line arguments and provides a GUI for the user to enter queries. It presents the top *k* matching terms in real time. When the user selects a term, the GUI opens up the results from a Google search for that term in a browser.

```
% java AutocompleteGUI cities.txt 7
```



Deliverables. Submit `Autocomplete.java`, `BinarySearchDeluxe.java`, and `Term.java`. Finally, submit a readme.txt (template included in project file) and answer the questions. To submit them:

```
% mkdir Lastname_Firstname_Lab5
# note: obviously, use your name instead of the placeholders
```

```
# copy your java files and readme file into this directory, e.g.
% cp Autocomplete.java BinarySearchDeluxe.java Term.java readme.txt Lastname_Firstnam
e_Lab5/
```

```
# before the next command, you should be in the directory containing the Lab5 folder
% tar czf Lastname_Firstname_Lab5.tgz Lastname_Firstname_Lab5
# this should produce a file called Lastname_Firstname_Lab5.tgz
```

```
# You can verify that it contains the expected files by creating a new
# directory and unzipping it in that new directory, such as:
% mkdir temp
% cp Lastname_Firstname_Lab5.tgz temp/
% cd temp
% tar xzf Lastname_Firstname_Lab5.tgz
% ls
% ls Lastname_Firstname_Lab5
```

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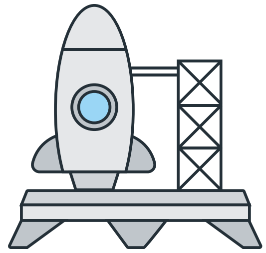

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Assignment

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