CSCI-1200 Data Structures — Fall 2021
Homework 4 — Visual Difference Lists

In this assignment we will compute and visualize the differences between two text files. We will use this assignment as a chance to review and practice using the STL `list` container class, as well as Big 'O' Notation and Recursion. *Please carefully read the entire assignment before beginning your implementation.*

To get started, let's study the sequence of words in these two input files:

`input_original.txt`
```
the quick brown fox jumped over the lazy dogs
```

`input_sample.txt`
```
the quick fox jumps over the big lazy dogs
```

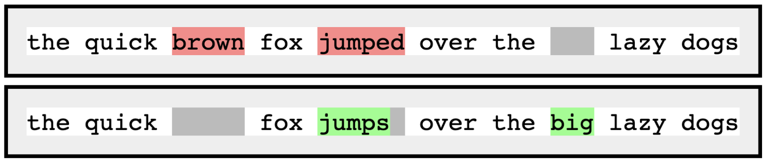
We can see 3 differences between the files: the word "`brown`" has been erased early in the sentence, the word "`jumped`" has been replaced by the word "`jumps`", and finally the word "`big`" has been inserted near the end of the sentence. We will represent these differences in the following file format:

`output_original_sample.diff`
```
2 ERASE
4 REPLACE "jumps"
7 INSERT "big"
```

The operations above are necessary and sufficient to transform the *original* text into the *sample* text. Each operation has an integer which indicates the position in the *original* file where the operation is performed. Given the original file and the operations to transform original to sample, we can also prepare the inverse list of operations necessary to go the opposite way (transform the *sample* text to the *original* text):

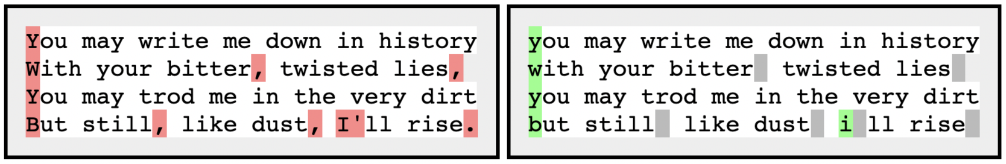
`output_sample_original.diff`
```
2 INSERT "brown"
3 REPLACE "jumped"
6 ERASE
```

We can visualize the edits discussed above using HTML background highlighting and any modern web browser (Chrome, Firefox, Safari, Edge, etc.). The pink areas have been erased or replaced, and the green areas have been replaced or inserted.



```
the quick brown fox jumped over the     lazy dogs
```
```
the quick       fox jumps  over the big lazy dogs
```

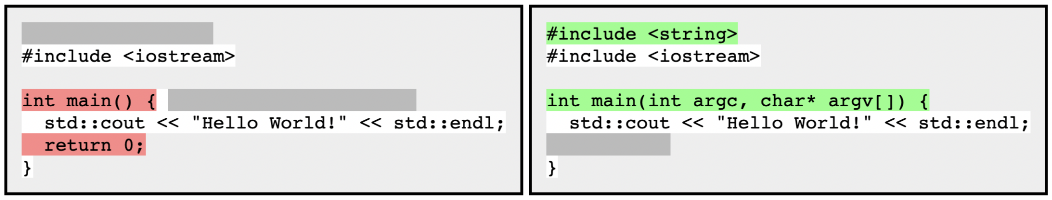
In the sample above, the unit for comparison was *words* separated by whitespace. But we can also do the comparison *per character* as illustrated in the example below, using the first paragraph of the poem *Still I Rise* by Maya Angelou. These are the operations necessary to remove all of the punctuation and replace the uppercase letters with the lowercase versions:



```
You may write me down in history
With your bitter, twisted lies,
You may trod me in the very dirt
But still, like dust, I'll rise.
```
```
you may write me down in history
with your bitter  twisted lies
you may trod me in the very dirt
but still  like dust  i ll rise
```

`output_still_i_rise_char.diff`
```
0 REPLACE "y"
33 REPLACE "w"
49 ERASE
63 ERASE
65 REPLACE "y"
98 REPLACE "b"
107 ERASE
118 ERASE
120 REPLACE "i"
121 ERASE
129 ERASE
```

This visualization technique is very helpful in collaborative software development projects. When one member of the team proposes changes to the code base, their requested changes can be visualized for review and approval by the other team members using a visual difference. Here is a small example where we consider the input as *whole lines* instead of words or characters as in the above examples.



```

#include <iostream>

int main() {
  std::cout << "Hello World!" << std::endl;
  return 0;
}
```

```
#include <string>
#include <iostream>

int main(int argc, char* argv[]) {
  std::cout << "Hello World!" << std::endl;

}
```

You can see more complex code difference visualizations on GitHub, https://github.com/, which hosts many open-source software development projects, including *Submitty*. Here's a recent *pull request* from one of the Submitty developers which changes multiple files in the code base:
https://github.com/Submitty/Submitty/pull/7128/files

Interactive and Incremental Commands for Testing and Debugging

We provide a framework of code to read and write most of the different input, output, and visualization files for this homework, but you must write several key functions to complete the program. You may not modify the provided code, except where indicated. Please study all of the provided code and the sample input and output files posted on the course web site.

The program accepts commands interactively from `std::cin` (the keyboard), but typically we will run the program by *redirecting* a text file of commands on the command line. See also "Redirecting Input & Output" from http://www.cs.rpi.edu/academics/courses/fall21/csci1200/programming_information.php. Here is a sample file of commands to visualize the first example in this handout:

requests_sample.txt
```
compute_diff WORD input_original.txt input_sample.txt output_original_sample.diff
render_diff WORD input_original.txt output_original_sample.diff output_original_sample.html
```

And here is the same example, saving more of the intermediate steps for inspection and debugging:

requests_sample_debugging.txt
```
compute_diff WORD input_original.txt input_sample.txt output_original_sample.diff
apply_diff WORD input_original.txt output_original_sample.diff output_applied.txt
assert_same WORD input_sample.txt output_applied.txt
invert_diff WORD input_original.txt output_original_sample.diff output_inverted.diff
apply_diff WORD input_sample.txt output_inverted.diff output_reapplied.txt
assert_same WORD input_original.txt output_reapplied.txt
compute_diff WORD input_sample.txt input_original.txt output_sample_original.diff
assert_same_diff WORD output_inverted.diff output_sample_original.diff
render_diff WORD input_original.txt output_original_sample.diff output_original_sample.html
```

The `main` function in `main.cpp` will parse these commands, read the necessary input files, call several functions you will implement, and write intermediate or final results to files (functions in `input_output.cpp` and `render.cpp`). You should make your own test cases for this assignment, and incrementally test each operation and inspect every output file. You must implement the missing functions, writing the function prototypes in a file named `solution.h` and implementing the body of the functions in `solution.cpp`.

This is how you will compile and run your program:

```
g++ main.cpp input_output.cpp render.cpp solution.cpp -Wall -Wextra -std=c++11 -o run.out
./run.out < requests_sample.txt
./run.out < requests_sample_debugging.txt
```

Study the same output files for this first example posted on the course website.

Multiple Solutions: Using Recursion to Find the Minimum Edit Distance

The most complex operation is the `compute_diff` function. We recommend saving the implementation of this function for last. Why is this a complicated problem? For some inputs there are many different combinations of insert, erase, and replace operations that when applied to the first file result in the second file. In particular, the problem is non-trivial if two or more adjacent/neighboring chars/words/lines must be erased, inserted, or replaced – as shown in the example below. Here are the visualizations of five different, valid ways to edit the original file resulting in the revised file:

`input_original.txt`

```
the quick brown fox jumped over the lazy dogs
```

`input_revised.txt`

```
yesterday the foolish and debatably quick brown fox jumped over dogs
```

`output_prioritize_erase.diff`

```
0 ERASE
1 ERASE
2 ERASE
3 ERASE
4 ERASE
5 ERASE
6 ERASE
7 ERASE
8 ERASE
9 INSERT "yesterday"
9 INSERT "the"
9 INSERT "foolish"
9 INSERT "and"
9 INSERT "debatably"
9 INSERT "quick"
9 INSERT "brown"
9 INSERT "fox"
9 INSERT "jumped"
9 INSERT "over"
9 INSERT "dogs"
```

`output_prioritize_insert.diff`

```
0 INSERT "yesterday"
1 INSERT "foolish"
1 INSERT "and"
1 INSERT "debatably"
6 INSERT "dogs"
6 ERASE
7 ERASE
8 ERASE
```

`output_prioritize_replace.diff`

```
0 REPLACE "yesterday"
1 REPLACE "the"
2 REPLACE "foolish"
3 REPLACE "and"
4 REPLACE "debatably"
5 REPLACE "quick"
6 REPLACE "brown"
7 REPLACE "fox"
8 REPLACE "jumped"
9 INSERT "over"
9 INSERT "dogs"
```

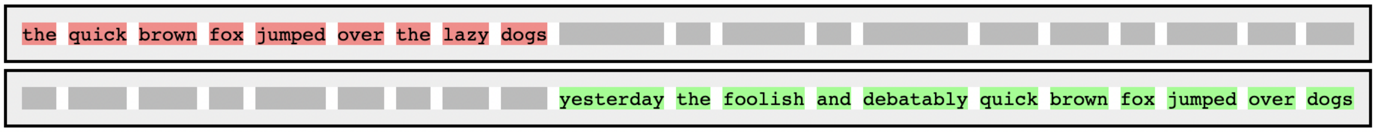
`output_default.diff`

```
0 INSERT "yesterday"
1 REPLACE "foolish"
2 REPLACE "and"
3 REPLACE "debatably"
4 REPLACE "quick"
5 REPLACE "brown"
6 REPLACE "fox"
7 REPLACE "jumped"
8 INSERT "over"
```

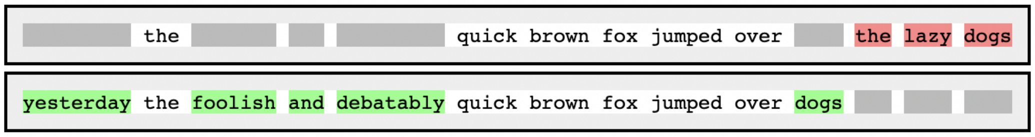
`output_recursive.diff`

```
0 INSERT "yesterday"
1 INSERT "foolish"
1 INSERT "and"
1 INSERT "debatably"
6 ERASE
7 ERASE
```

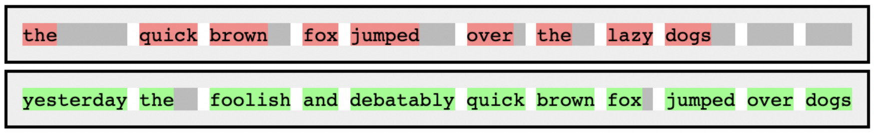
`output_prioritize_erase.diff`


the quick brown fox jumped over the lazy dogs
yesterday the foolish and debatably quick brown fox jumped over dogs

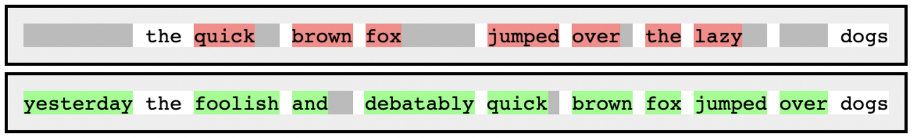
`output_prioritize_insert.diff`


the quick brown fox jumped over the lazy dogs
yesterday the foolish and debatably quick brown fox jumped over dogs

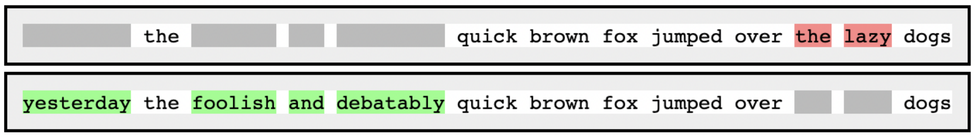
`output_prioritize_replace.diff`


the quick brown fox jumped over the lazy dogs
yesterday the foolish and debatably quick brown fox jumped over dogs

`output_default.diff`


the quick brown fox jumped over the lazy dogs
yesterday the foolish and debatably quick brown fox jumped over dogs

`output_recursive.diff`


the quick brown fox jumped over the lazy dogs
yesterday the foolish and debatably quick brown fox jumped over dogs

And this represents only a few of the many possible answers for this small problem. How do we decide which one is best? How do we find the best answer? Usually we decide that the *best or optimal solution* has the fewest total insert, erase, and replace operations (e.g., shortest length of `.diff` file). This is the *Minimum Edit Distance* problem – a dynamic programming problem that is often covered in Intro to Algorithm courses. **IMPORTANT NOTE: For this homework, we are not asking you for an efficient, optimal solution to every input, which is beyond the scope of this course!**. You should not search for, read in detail, or use any code available online to solve this problem.

We can compute the optimal solution for small problems by writing a recursive search. You may implement an option to perform the recursive search for *extra credit*. Caution: This search is very expensive! As you test your recursive function you will appreciate how quickly this search becomes impractical for larger examples.

So instead of finding the optimal solution, everyone's non-extra-credit solution for `compute_diff` should efficiently find a good solution for inputs that *do not require editing two or more adjacent/neighboring chars/words/lines*. The rest of the code should correctly work with and visualize `.diff` files produced from any `compute_diff` algorithm, as shown above and available on the course website. You do *not* need to implement multiple versions/algorithms for the `compute_diff` operation.

Additional Assignment Requirements and Suggestions

- **You may not use vectors or arrays or subscript [] for this assignment.** Use STL lists instead. You may not use maps, or sets, or things we haven't seen in class yet. Be sure to use const and pass/return by reference where appropriate (refer to the diagram in Lecture 8).
- You should practice using a traditional debugger, e.g., `gdb/lldb` with this assignment. Set breakpoints, walk line-by-line through loops or function calls, print variables, examine stack frames, etc. Even though you will not be directly calling `new` or `delete` yourself, you may find a memory debugger, e.g., `drmemory` or `valgrind` helpful if you get stuck with a segmentation fault or other memory error.
- In your README.txt file, provide a Big O Notation complexity analysis of each operation/function in the program assuming w words in the first input file, and requiring i inserts, e erases, and r replace operations. Write a few sentences justifying each of your answers.
- Be sure to make up new test cases to fully test your program. Use the template `README.txt` to list your collaborators, your time spent on the assignment, and any notes you want the grader to read.