CSCI 330 Assignment 5 (Spring 2021)

dog: it's better than cat (100 pts)

Purpose

This assignment is meant to give students practice working on projects that contain multiple source code files. It will require the students to construct a Makefile and appropriate header files. It will also require the use of `getopt` to handle command line options, and manipulation of data read in from a file.

You must use `read (2)` for all input and `write (2)` for all output (excluding error messages, for which you may use `perror` and/or the `cerr` stream object). The use of `getopt (3)` is not required but is strongly recommended.

Description

For this assignment, you will take the `cat` program you wrote for the last assignment and upgrade it to add more features. We will call it `dog` instead of `cat`, because dogs are kind of like cats, but way better. These new features will include:

- The ability to change the size of the buffer used for calls to read and write to `N` bytes when passed the command line option (`-s N`).
- The ability to change the number of bytes read from each file before finishing to `N` when supplied with the command line option (`-n N`). This is instead of reading the whole file as we would have without this option.
- The ability to apply a Caesar cipher with a shift of `k` letters to alphabetical characters in the data read in before writing the results when it receives the command line option (`-c k`).
- The ability to apply a general rotation (Caesar shift for *all* characters, not just letters) with a shift of `k` to the input data before writing it back out when supplied with the command line option (`-r k`).
- The ability to output the data from the file in hexadecimal format when supplied the command line option (`-x`).
- The ability to output the data from the file in binary notation, most significant bit first, when supplied the command line option (`-b`)

Requirements

- The main loop should be in your `main` function in one source code file. The functions that process the data (Caesar cipher/binary/hex/rotation) should be found in another file. Their declarations will need to be in a header file, so that they can be called from `main` even though they will be implemented in that other file.
- You must make a `Makefile` that has rules sufficient to compile your program when a user types `make` in the same directory as your source code. Only files that have changed or that have had their dependencies change should be recompiled.
- You must use the system calls `read` for the input from the files and `write` for the output. You may use `cerr` and `perror` to display error messages, but `cout` is disallowed, as are `printf` and `fprintf`, for the output data.
- Obviously, your source code must be well documented. If it is not, there will be a large point penalty. This requirement holds for all coding assignments in this course, whether this line is in the description of the assignment or not.
- The features enabled by the command line options listed in the description section above must be implemented.

- Note: If both `-r` and `-c` are specified, the behavior can change depending on which is executed first. Don't allow a user to specify both. Give them an error message and `exit` if they try.
- Also: Binary and hexadecimal notation flags are mutually exclusive, as it would not be possible to represent the data as both simultaneously. If both binary and hexadecimal modes are specified, it is an error. Print a warning and quit.
- The other command line parameters can all be on at the same time without any problem. Make sure that they work together.

- If no command line options are specified, this program should behave the same as `cat` would have, as was specified in the previous program.

Caesar cipher

A Caesar cipher is a very primitive method of encrypting text data. It involves taking the letters of the input and shifting them upwards alphabetically by some number of letters. This number is given as the option parameter in the command line option that turns on the Caesar shift. If that parameter was not an integer, do not perform any shift. Only letters (uppercase and lowercase) should have any shift applied at all. Leave any other characters untouched. You should assume the files are using the ASCII encoding for this purpose. (`man 7 ascii`).

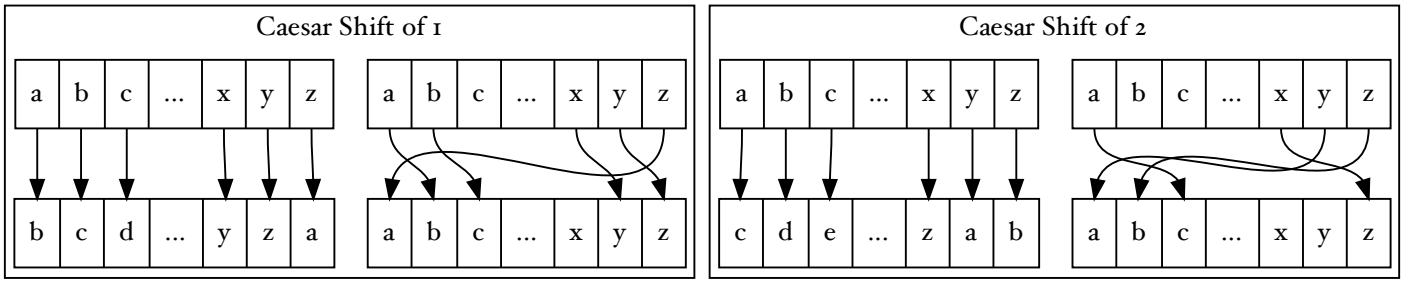


Figure 1: A diagram of the basic Caesar shift cipher for shifts of one and two.

Binary rotation

While the Caesar cipher above was interpreting the bytes that you read as text, changing only alphabetical characters, this option should apply to any value, alphabetical or not. The principle is the same, but instead of applying it to `A-Z` and `a-z`, it is applied to each one-byte value interpreted as `0-255`.

Hexadecimal representation

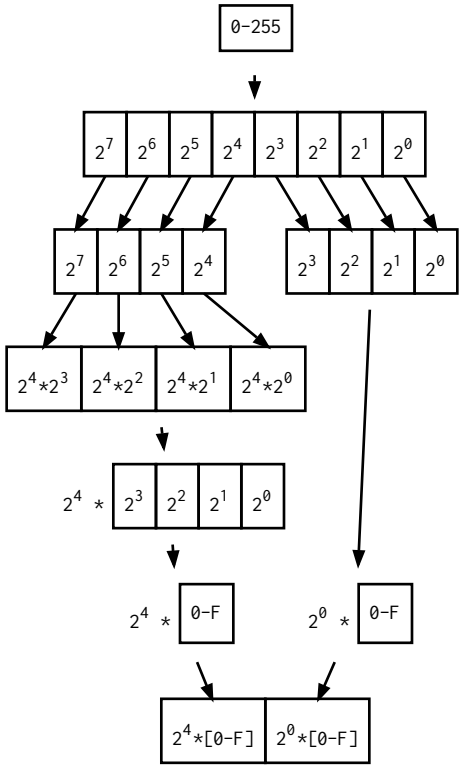
All numbers are stored as collections of binary bits on the computer. A `char` is one byte long, which is eight bits. When dealing with files that are not meant to be read by a human (binary mode as opposed to text mode), it can be convenient to encode the data in a format called hexadecimal.

Hexadecimal, the base-16 number system, is useful because it is based on a power of 2 ($2^4 = 16$), and so each hexadecimal digit represents 4 bits. Numbers represented as decimal (base-10) do not line up in the same way, so it can be hard to know which bits are on and which are off.

Each byte is composed of *eight* bits, and can be represented as *two* hex digits. Your program should be able to output the data in this format (2 hex digits per input byte) whenever the `-x` command line parameter is enabled. Keep in mind that there will be two characters of output for every character of input in this mode.

Since you are not allowed to use `cout` for the output, you won't be able to use the `hex` IO manipulator to accomplish this. Likewise, functions from the `printf` family using a format of `%x` are not permitted either.

Hint: You can use the bitwise operators in C++ (`&`, `|`) to isolate the high order 4 bits from the low order 4 bits in a byte, and the bitshift operators (`>>`, `<<`) can make the high order ones easier to deal with.



Decimal	Hex	Binary
0	0	0000
1	1	0001
2	2	0010
3	3	0011
4	4	0100
5	5	0101
6	6	0110
7	7	0111
8	8	1000
9	9	1001
10	A	1010
11	B	1011
12	C	1100
13	D	1101
14	E	1110
15	F	1111

Figure 2: A diagram illustrating how the bits of a byte can be represented in hexadecimal notation.

Binary representation

$$\texttt{value} = 128b_7 + 64b_6 + 32b_5 + 16b_4 + 8b_3 + 4b_2 + 2b_1 + 1b_0 = \sum_{i=0}^{7} 2^i b_i$$

Every byte is made up of *eight* bits, b_0 to b_7, each of which is true (`1`) or false (`0`). When interpreting them as an unsigned number, each bit, b_i, answers the question of whether 2^i should be added into the sum making up the number represented. When you output the data in binary format, you will output a `1` if the bit is true, or a `0` if the bit is false, for all eight bits, starting from the most significant one (b_7, which represents 128). Notice that the output data will be eight times longer than the input data.

Some examples of output

```
% cat file1
Hello World
% ./dog file1
Hello World
% ./dog -n 5 file1
Hello
% ./dog -n 5 -c 1 file1
Ifmmp
% ./dog -n 5 -x file1
65486c6c6f
% ./dog -n 5 -b file1
0110010101001000011011000110110001101111
```

What to turn in?

Submit, through Blackboard, the following files:

- The C++ source file (`.cc`) containing your `main` function and no others.
- The C++ source file (`.cc`) containing the functions implementing the new features added.
- A C++ header file (`.h`) containing the declarations for each of the functions implementing the new features.
- A `Makefile` that will compile your program. The rules should be set up so that only the files that have changed need to be recompiled.

Remember, there is **no credit for late work.**