

COS 284, Spring 2020

Data Lab: Manipulating Bits

1 Introduction

The purpose of this assignment is to become more familiar with bit-level representations of numeric values. You'll do this by solving a series of programming "puzzles." Many of these puzzles are quite artificial, but you'll find yourself thinking much more about bits in working your way through them.

2 Logistics

Unless otherwise specified, you should work in a group of two people to solve the problems for this assignment. The only "hand-in" will be electronic. Any clarifications and revisions to the assignment will be posted on the web site.

3 Handout Instructions

Download [the lab handout](#), a file called `datalab-handout.tar`, from the course home page. This file is the Unix equivalent of a `.zip` file, so it contains multiple files within it.

Start by copying `datalab-handout.tar` to a (protected) directory on the Linux machine in which you plan to do your work. Then give the command

```
unix> tar xvf datalab-handout.tar.
```

This will cause a number of files to be unpacked in the directory. The only file you will be modifying and turning in is `bits.c`.

The `bits.c` file contains a skeleton for each of the programming puzzles. Your assignment is to complete each function skeleton using only *straightline* code for the integer puzzles (i.e., no loops or conditionals) and a limited number of C arithmetic and logical operators. Specifically, you are *only* allowed to use the following eight operators:

```
! ~ & ^ | + << >>
```

A few of the functions further restrict this list. Also, **you are not allowed to use any constants longer than 8 bits**. See the comments in `bits.c` for detailed rules and a discussion of the desired coding style.

4 The Puzzles

This section describes the puzzles that you will be solving in `bits.c`.

Table 1 lists the puzzles. The “Rating” field gives the difficulty rating (the number of points) for the puzzle, and the “Max ops” field gives the maximum number of operators you are allowed to use to implement each function. See the comments in `bits.c` for more details on the desired behavior of the functions. You may also refer to the test functions in `tests.c`. These are used as reference functions to express the correct behavior of your functions, although they don’t satisfy the coding rules for your functions.

Name	Description	Rating	Max ops
<code>bitXor(x, y)</code>	$x \oplus y$ using only <code>&</code> and <code>~</code> .	1	14
<code>tmin()</code>	Smallest two’s complement integer	1	4
<code>isTmax(x)</code>	True only if x is largest two’s comp. integer.	1	10
<code>allOddBits(x)</code>	True only if all odd-numbered bits in x set to 1.	2	12
<code>negate(x)</code>	Return $-x$ with using <code>-</code> operator.	2	5
<code>isAsciiDigit(x)</code>	True if $0x30 \leq x \leq 0x39$.	3	15
<code>conditional</code>	Same as $x ? y : z$	3	16
<code>isLessOrEqual(x, y)</code>	True if $x \leq y$, false otherwise	3	24
<code>logicalNeg(x)</code>	Compute $!x$ without using <code>!</code> operator.	4	12
<code>howManyBits(x)</code>	Min. no. of bits to represent x in two’s comp.	4	90

Table 1: Datalab puzzles

5 Evaluation

Your score will be computed out of a maximum of 76 points based on the following distribution:

50 Correctness points.

40 Performance points.

10 Style points.

Correctness points. The puzzles you must solve have been given a difficulty rating between 1 and 4, such that their weighted sum totals to 50. We will evaluate your functions using the `btest` program, which is described in the next section. You will get full credit for a puzzle if it passes all of the tests performed by `btest`, and no credit otherwise.

Performance points. Our main concern at this point in the course is that you can get the right answer. However, we want to instill in you a sense of keeping things as short and simple as you can. Furthermore, some of the puzzles can be solved by brute force, but we want you to be more clever. Thus, for each function we’ve established a maximum number of operators that you are allowed to use for each function. This limit

is very generous and is designed only to catch egregiously inefficient solutions. You will receive two points for each correct function that satisfies the operator limit.

Style points. Finally, we’ve reserved 10 points for a subjective evaluation of the style of your solutions and your commenting. Your solutions should be as clean and straightforward as possible. Your comments should be informative, but they need not be extensive.

Extra credit. You will receive 1 extra point for each function that does better than the professor’s standard submission. If you “beat the prof” (\geq the prof on all functions), you will receive an additional 5 extra points.

Autograding your work

We have included autograding tools in the handout directory — `btest`, `dlc`, and `driver.pl` — to help you check the correctness of your work.

- **btest:** This program checks the functional correctness of the functions in `bits.c`. To build and use it, type the following two commands:

```
unix> make
unix> ./btest
```

Notice that you must rebuild `btest` each time you modify your `bits.c` file.

You’ll find it helpful to work through the functions one at a time, testing each one as you go. You can use the `-f` flag to instruct `btest` to test only a single function:

```
unix> ./btest -f bitAnd
```

You can feed it specific function arguments using the option flags `-1`, `-2`, and `-3`:

```
unix> ./btest -f bitAnd -1 7 -2 0xf
```

Check the file `README` for documentation on running the `btest` program.

- **dlc:** This is a modified version of an ANSI C compiler from the MIT CILK group that you can use to check for compliance with the coding rules for each puzzle. The typical usage is:

```
unix> ./dlc bits.c
```

The program runs silently unless it detects a problem, such as an illegal operator, too many operators, or non-straightline code in the integer puzzles. Running with the `-e` switch:

```
unix> ./dlc -e bits.c
```

causes `dlc` to print counts of the number of operators used by each function. Type `./dlc -help` for a list of command line options.

- **driver.pl:** This is a driver program that uses `btest` and `dlc` to compute the correctness and performance points for your solution. It takes no arguments:

```
unix> ./driver.pl
```

Your instructors will use `driver.pl` to evaluate your solution.

6 Submission Instructions

Use the course web site to submit your lab. Only one person per group needs to turn in the `bits.c` file using the following instructions. The file has a section to identify who you are; be sure to include both your names. Also, be sure to remove any print statements you added for debugging.

7 Advice

- Don't include the `<stdio.h>` header file in your `bits.c` file, as it confuses `dlc` and results in some non-intuitive error messages. You will still be able to use `printf` in your `bits.c` file for debugging without including the `<stdio.h>` header, although `gcc` will print a warning that you can ignore.
- The `dlc` program enforces a stricter form of C declarations than is the case for C++ or that is enforced by `gcc`. In particular, any declaration must appear in a block (what you enclose in curly braces) before any statement that is not a declaration. For example, it will complain about the following code:

```
int foo(int x)
{
    int a = x;
    a *= 3;      /* Statement that is not a declaration */
    int b = a;   /* ERROR: Declaration not allowed here */
}
```

8 The “Beat the Prof” Contest

For fun, we're offering an optional “Beat the Prof” contest that allows you to compete with other students and the instructor to develop the most efficient puzzles. The goal is to solve each Data Lab puzzle using the fewest number of operators. Students who match or beat the instructor's operator count for each puzzle are winners!

To submit your entry to the contest, type:

```
unix> ./driver.pl -u 'Your Nickname'
```

Nicknames are limited to 35 characters and can contain alphanumerics, apostrophes, commas, periods, dashes, underscores, and ampersands. You can submit as often as you like. Your most recent submission will appear on a real-time scoreboard, identified only by your nickname. You can view the scoreboard by pointing your browser at

`http://ics.cse.taylor.edu:8080`