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# CS:APP Data Lab  
# Directions to Instructors  
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# May 31, 2011: Now includes the "Beat the Prof" contest  
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# Copyright (c) 2002-2018, R. Bryant and D. O'Hallaron  
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```

This directory contains the files that you will need to run the CS:APP Data Lab, which helps develop the student's understanding of bit representations, two's complement arithmetic, and IEEE floating point.

For fun, we've also provided a new user-level HTTP-based "Beat the Prof" contest that replaces the old email-based version. The new contest is completely self-contained and does not require root password. The only requirement is that you have a user account on a Linux machine with an IP address.

System requirements: Uses bison and flex to build dlc.

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1. Overview  
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In this lab, students work on a C file, called `bits.c`, that consists of a series of programming "puzzles". Each puzzle is an empty function body that must be completed so that it implements a specified mathematical function, such as "absolute value". Students must solve the non-floating point puzzles using only straight-line C code and a restricted set of C arithmetic and logical operators. For the floating-point puzzles they can use conditionals and arbitrary operators.

Students use the following three tools to check their work. Instructors use the same tools to assign grades.

1. `dlc`: A "data lab compiler" that checks each function in `bits.c` for compliance with the coding guidelines, checking that the students use less than the maximum number of operators, that they use only straight-line code, and that they use only legal operators. The sources and a Linux binary are included with the lab.

2. `btest`: A test harness that checks the functions in `bits.c` for correctness. This tool has been significantly improved, now checking wide swaths around the edge cases for integers and floating point representations such as 0, `Tmin`, denorm-norm boundary, and `inf`.

3. `driver.pl`: A autograding driver program that uses `dlc` and `btest` to check each test function in `bits.c` for correctness and adherence to the coding guidelines

The default version of the lab consists of 15 puzzles, in `./src/selections.c`, chosen from a set of 73 standard puzzles defined in the directory `./src/puzzles/`. You can customize the lab from term to term by choosing a different set of puzzles from the standard set of puzzles.

You can also define new puzzles of your own and add them to the standard set. See `./src/README` for instructions on how to add new puzzles to the standard set.

NOTE: If you define new puzzles, please send them to me (Dave O'Hallaron, `droh@cs.cmu.edu`) so that I can add them to the standard set of puzzles in the data lab distribution.

2. Files

All CS:APP labs have the same simple top-level directory structure:

<code>Makefile</code>	Builds the entire lab.
<code>README</code>	This file.
<code>src/</code>	Contains all source files for the lab.
<code>datalab-handout/</code>	Handout directory that goes to the students. Generated by the Makefile from files in <code>./src</code> . Never modify anything in this directory.
<code>grade/</code>	Autograding scripts that instructors can use to grade student handins.
<code>writeup/</code>	Sample Latex lab writeup.
<code>contest/</code>	Everything needed for the optional "Beat the Prof" contest.

3. Building the Lab

Step 0. If you decide to run the "Beat the Prof" contest (section 5), then edit the `./contest/Contest.pm` file so that the driver knows where to send the results. See `./contest/README` for the simple instructions. If you decide *not* to offer the contest, then do nothing in this step.

Step 1. Select the puzzles you want to include by editing the file `./src/selections.c`.

The default `./src/selections.c` comes from a previous instance of the Data Lab at CMU. The file `./src/selections-all.c` contains the complete list of puzzles to choose from.

Step 2. Modify the Latex lab writeup in `./writeup/datalab.tex` to tailor it for your course.

Step 3. Type the following in the current directory:

```
unix> make clean
unix> make
```

The Makefile generates the `btest` source files, builds the `dlc` binary (if necessary), formats the lab writeup, and then copies `btest`, the `dlc` binary, and the driver to the handout directory. After that, it builds a tarfile of the handout directory (in `./datalab-handout.tar`) that you can then hand out to students.

Note on Binary Portability: `dlc` is distributed in the `datalab-handout` directory as a binary. Linux binaries are not always portable across distributions due to different versions of dynamic libraries. You'll need to be careful to compile `dlc` on a machine that is compatible with those that the students will be using.

Note: Running "make" also automatically generates the solutions to the puzzles, which you can find in `./src/bits.c` and `./src/bits.c-solution`.

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4. Grading the Lab
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There is a handy autograder script that automatically grades your students' handins. See `./grade/README` for instructions.

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5. "Beat the Prof" Contest
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For fun, we've included an optional "Beat the Prof" contest, where students compete against themselves and the instructor. 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. See `./contest/README` for the simple instructions on how to set up the contest.

NOTE: The contest is completely optional. Whether you decide to offer it or not has no affect on how you build and distribute the lab.

NOTE: If you do decide to offer the contest, then you should configure the contest *before* you build the lab, so that the driver knows the server and port to send the contest results of each student (using the constants defined in the `./src/Driverhdrs.pm` file, which is autogenerated from the `./contest/Contest.pm` config file).

If you decide to offer the contest *after* you've built and handed out the lab to the students, you're still OK:

- 1) Configure the contest as described in `contest/Makefile`
- 2) Rebuild the lab in the usual way:

```
linux> cd datalab
linux> make
```
- 3) Distribute the new `./src/Driverhdrs.pm` file to the students.

 6. Experimental BDD checker

For fun, we have included an experimental correctness checker based on binary decision diagrams (BDDs) (R. E. Bryant, IEEE Transactions on Computers, August, 1986) that uses the CUDD BDD package from the University of Colorado. The BDD checker does an exhaustive test of the test functions in `bits.c`, formally verifying the correctness of each test function against a reference solution for *ALL* possible input values. For functions that differ from the reference solution, the BDD checker produces a counterexample in the form of a set of function arguments that cause the test solution to differ from the reference solution.

The sources are included in `./src/bddcheck`. To compile:

```
unix> cd src/bddcheck
unix> make clean
unix> make
```

To use BDDs to check `./src/bits.c` for correctness:

```
unix> cd src
unix> ./bddcheck/check.pl      # with error messages and counterexamples
unix> ./bddcheck/check.pl -g  # compact tabular output with no error messages
```

Note that `check.pl` must be run from the parent directory of `./bddcheck`.

We've been using this BDD checker instead of btest at CMU for several years and the code appears to be stable. The main weakness is in the Perl code that extracts the functions from bits.c. It usually works, but some things -- such as calls to other functions, or functions that don't end with a single brace -- confuse it. So we're reluctant to make it the default checker for the distributed CS:APP labs. However, if you have any questions about the correctness of a particular solution, then this is the authoritative way to decide.

Please send any comments about the BDD checker to randy.bryant@cs.cmu.edu.