

# CS 111: Operating System Principles

## Lab 3

# Hash Hash Hash 3.0.0

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In this lab you'll be making a hash table implementation safe to use concurrently. You'll be given a serial hash table implementation, and two additional hash table implementations to modify. You're expected to implement two locking strategies and compare them with the base implementation. The hash table implementation uses separate chaining to resolve collisions. Each cell of the hash table is a singly linked list of key/value pairs. You are not to change the algorithm, only add mutex locks. Note that this is basically the implementation of Java concurrent hash tables, except they have an optimization that doesn't create a linked list if there's only one entry at a hash location.

**Additional APIs.** Similar to Lab 2, the base implementation uses a linked list, but instead of TAILQ, it uses SLIST. You should note that the SLIST\_ functions modify the pointers field of struct list\_entry. For your implementation you should only use pthread\_mutex\_t, and the associated init/lock/unlock/destroy functions. You will have to add the proper #include yourself.

**Starting the lab.** Run the following command to get the skeleton for Lab 3: git pull upstream main. You should be able to run make in the lab3 directory to create a hash-table-tester executable, and then make clean to remove all binary files. The executable takes two command line arguments: -t changes the number of threads to use (default 4), and -s changes the number of hash table entries to add per thread (default 25,000). For example you can run: ./hash-table-tester -t 8 -s 50000.

**Files to modify.** You should only be modifying hash-table-v1.c, hash-table-v2.c, and README.md in the lab3 directory.

**Tester Code.** The tester code generates consistent entries in serial such that every run with the same -t and -s flags will receive the same data. All hash tables have room for 4096 entries, so for any sufficiently large number of additions, there will be collisions. The tester code runs the base hash table in serial for timing comparisons, and the other two versions with the specified number of threads. For each version it reports the number of  $\mu s$  per implementation. It then runs a sanity check, in serial, that each hash table contains all the elements it put in. By default your hash tables should run -t times faster (assuming you have that number of cores). However, you should have missing entries (we made it fail faster!). Correct implementations should at least have no entries missing in the hash table. However, just because you have no entries missing, you still may have issues with your implementation (concurrent programming is significantly harder).

**Your task.** Using only pthread\_mutex\_\*, you should create two thread safe versions of the hash table "add entry" functions. You only have to add locking calls to hash\_table\_v1\_add\_entry and hash\_table\_v2\_add\_entry, all other functions are called serially, mainly for sanity checks. By default there is a data race finding and adding entries to the list. You'll need to fill in your README.md completely. Most sections are what you expect from previous labs, however there is more to add for this lab (explained below).

For the first version, v1, you should only be concerned with correctness. Create a **single** mutex, only for v1, and make hash\_table\_v1\_add\_entry thread safe by adding the proper locking calls. Remember, you should only modify code in hash-table-v1.c. You'll have to explain why your implementation is correct in your README.md. You should test it versus the base hash table implementation and also add your findings to README.md.

For the second version, v2, you should be concerned with correctness and performance. You can now create as many mutexes as you like in hash-table-v2.c. Make hash\_table\_v2\_add\_entry thread safe by adding the proper locking calls. Similar to the first version, you'll need to explain why your implementation is correct, test its performance against the previous implementations, and add your findings to README.md.

In both cases you may add fields to any hash table struct: the hash table, hash\_table\_entry, or list\_entry. Your code changes should not modify contains or get\_value. Any other code modifications are okay. However, you should not change any functionality of the hash tables.

**Errors.** You will need to check for errors for any `pthread_mutex_*` functions you use. You may simply exit with the proper error code. You are expected to destroy any locks you create. The given code passes `valgrind` with no memory leaks, you should not create any.

**Tips.** Since this is a lab about concurrency and parallelism, you may want to significantly increase the number of cores given to your virtual machine, or run your code on a Linux machine with more cores.

**Example output.** You should be able run:

```
> ./hash-table-tester -t 8 -s 50000
Generation: 130,340 usec
Hash table base: 1,581,974 usec
  - 0 missing
Hash table v1: 359,149 usec
  - 28 missing
Hash table v2: 396,051 usec
  - 24 missing
```

**Testing.** There are a set of basic test cases given to you (they'll be released a few days after the lab). We'll withhold more advanced tests which we'll use for grading. Part of programming is coming up with tests yourself. To run the provided test cases please run the following command in your lab directory:

```
python -m unittest
```

**Submission.** Simply push your code using `git push origin main` (or simply `git push`) to submit it. *You need to create your own commits to push, you can use as many as you'd like.* You'll need to use the `git add` and `git commit` commands. You may push as many commits as you want, your latest commit that modifies the lab files counts as your submission. For late days we will look at the timestamp on our server. We will never use your commit times (or file access times) as proof of submission, only when you push your code to the course Git server.

We've created a new system for the fall quarter that double checks you have the latest upstream code and have submitted something. Please check <https://laforge.cs.ucla.edu/cs111/grades/> to see your status. You're expected to properly merge in upstream code without rebasing. Note that the website only updates your lab modification status if you've merged the latest code.