CSc 460 — Database Design
Fall 2020 (McCann)

http://u.arizona.edu/~mccann/classes/460

Program #2: Linear Hashing Lite

Due Date: September 24th, 2020, at the beginning of class

Overview: In class we have covered (or very soon will cover) Dynamic Hashing and Extendible Hashing indices. Both require a directory. In 1980 Witold Litwin introduced Linear Hashing, a directory–free hash–based indexing structure. In this assignment, you'll implement what we'll call Linear Hashing Lite[1] (LHL) and use it to assist the querying of a binary file.

Assignment: This assignment is in two parts, both of which have the same due date.

Part 1 Write a program named `Prog21.java` that creates, in a binary file named `lhl.idx`, a Linear Hashing Lite index for the `MeteoriteLandings.bin` database file of meteorite records created by your `Prog1A.java` program. Write your program to store `lhl.idx` in the current directory (that is, do not append any path information to the file name), and to accept the complete path to `MeteoriteLandings.bin` as the command–line argument. The index is to be constructed using the 'id' field (the second field) as the key, the values of which should be unique across the meteorites. See the last page of this handout for the description of LHL.

For this implementation of LHL, the buckets will have a maximum capacity of 50 index records. Initially, the index will consist of two empty buckets, $H = 0$, and the hash function will be $h_H(k) = k \ \% \ (2^{H+1})$.

After the index file has been created, display (a) the number of buckets in the index, (b) the number of records in the lowest–occupancy bucket, (c) the number of records in the highest-occupancy bucket, and (d) the mean of the occupancies across all buckets.

Part 2 The second task is to write a program named (you guessed it) `Prog22.java` that processes a simple variety of query with the help of your LHL index. The complete paths to both the `lhl.idx` index file and the `MeteoriteLandings.bin` database file are provided, in that order, as command–line arguments. Use a loop to prompt the user to enter any number of key values, one at a time. If the key matches an 'id' value in the LHL index, display the same three values from the corresponding DB file record in the database file as you displayed in Program #1, and in the same format. Otherwise, display the message "The key value '#####' was not found." (Of course, display the actual key, not a bunch of pound signs!)

In order to successfully write `Prog22.java`, you may decide that you need to communicate to it some metadata about the index created by `Prog21.java`. Program #1 gave you some experience doing that sort of thing. You may do the same sort of thing in this assignment. Keep in mind that your index's size will vary based on the number of records in the DB file (binary file) your `Prog1A.java` creates, much as your binary file's size varies based on the CSV file's content.

Data: We will use your own `MeteoriteLandings.bin` file to test your programs, which means that you will need to submit it using `turnin`. You may also submit your current `Prog1A.java` program, if you wish to do so. Why would you want to? If the TAs have a problem with your binary file and have your program that generates it, they can try to recreate it.

As for dreaming up queries for testing, that's up to you (but shouldn't be too hard). We'll test with a variety of 'id' field values (present and not). Thus, so should you. Control `Prog22.java` the same way you controlled the execution of `Prog1B.java`, terminating when a zero 'id' value is entered.

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[1] One-third fewer headaches than regular Linear Hashing, but the same great taste!

Output: The basic output expectations of `Prog21.java` and `Prog22.java` are given with their descriptions, above.

Hand In: You are required to submit your completed program files (`Prog21.java` and `Prog22.java`), and your `MeteoriteLandings.bin` file on which those programs operate, using the `turnin` facility on lectura. The submission folder is `cs460p2`. Optionally, you may also provide your current `Prog1A.java` program. Submit all files as–is; that is, **do not 'package' them** into ZIP or TAR files.

Because we will be grading your program on lectura, it needs to run on lectura. This means that you need to test it on lectura. Name your main program source files as directed above, so that we don't have to guess which files to compile, but feel free to split up your code over additional files if you feel that doing so is appropriate.

Want to Learn More?

Remember: What this assignment requires is *not* the full version of Linear Hashing described in these papers; I'm referencing them to satisfy the curious among you.

- Lots of copies of Litwin's original Linear Hashing paper are floating around the internet, because the official source isn't readily available. If you want to read it, you can get the title from here, and use it to search for a PDF: `http://www.vldb.org/dblp/db/conf/vldb/vldb80.html`
- A somewhat more approachable description of Linear Hashing can be found as part of the paper "Dynamic hash tables" by Per–Ake (Paul) Larson: `http://dl.acm.org/citation.cfm?doid=42404.42410`

Other Requirements and Hints:

- Comment your code according to the style guidelines *as you write the code* (not an hour before class!).
- Work on just a part of the assignment at a time; don't try to code it all before you test any of it. Don't be afraid to do things a little bit backwards; for example, it's nice to have a basic query program in place to help you test the construction of your index.
- You can make debugging easier by using only a small amount of data with very small buckets as you develop the code, and switch to the complete data file and full–size buckets when everything seems to be working.
- As always: **Start early!** We don't have an early, first–part due–date on this one; you'll have to do your own planning.

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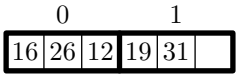
Linear Hashing Lite: The Basics

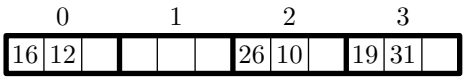
Like Dynamic and Extendible Hashing, Linear Hashing was created for indexing. Unlike them, Linear Hashing does not use a directory as its hash function. Instead, it relies on a characteristic of division–based hash functions, thus so does our simplified version, described on this page.

Insertion

Consider two hash buckets, which, for this demonstration, are each capable of holding at most $bf = 3$ index records, and the simple hash function $h(k) = k \,\%\, 2$. The result of hashing the key values 16, 19, 26, 31, and 12 is:



To store the key value 10, we need to expand the hash table and change the hash function. Specifically, we will change the hash function to be $h(k) = k \,\%\, 4$ (double the divisor), and double the number of buckets in the table (to match the range of the new function). We also need to re–distribute (re–hash) the existing key values. Because of our choice of hash functions, this isn't a typical re–hash: The values currently in bucket 0 will either stay there, or will move to bucket 2. Similarly, those in bucket 1 will stay or move to bucket 3. (Why this happens is left as an exercise for the reader.) After the re–hashing, and after the insertion of 10, the table looks like this:



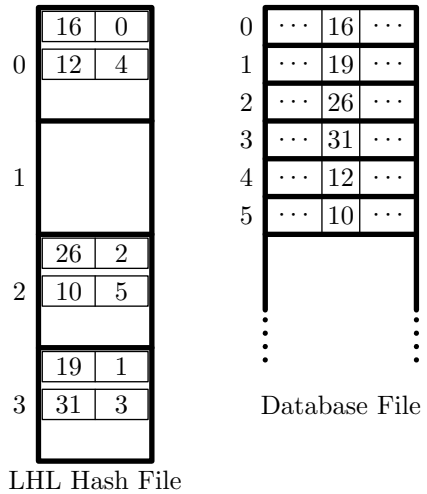
Each time we need to insert into a full bucket, the same steps are performed: We double the divisor of the hash function, double the number of buckets in the hash table, re–hashing the existing values, and insert the new key. Each time we re–hash the content of a bucket, the entries either stay in the same bucket, or move to just one of the new buckets. This property helps minimize I/O operations.

Performing insertions for this assignment is a bit more involved. We discover the keys to be inserted by sequentially reading the records in the binary file created by `Prog1A.java` (the Database File in the figure below). As we read the records, we also note their locations (here, their record numbers, if you imagine the file as an array of records). Together, the key and the record number form the index record that is inserted into the hash bucket. It is helpful to parameterize the hash function. That is, instead of $h(k)$, express the hash function as $h(k, H) = k \,\%\, (2^{H+1})$, where $H = 0$ initially and increases by one whenever the hash table grows. (Note that the number of buckets in the hash table is the same as the hash function's divisor, 2^{H+1}.)

Searching

Searching a Linear Hashing Lite index is straight-forward: Using the key to be located (the *target*) and the last value of H, locate and read the bucket of the hash file that contains (or would contain) the target. Sequentially search the bucket content to see if the target is there. If it is, use the paired DB file record number to access the fields you need to output.

For example, consider the figures to the right (an enhanced version of the above insertion example) and the target value 31. Our last value of H was 1. $h(k, H) = h(31, 1) = 31 \,\%\, (2^{1+1}) = 3$. Reading and searching bucket 3 locates 31's index record, which contains the record number of 31's complete record in the database file (in this example, the record number is 3). Reading that record provides 31's associated data, allowing the query to be completed.



LHL Hash File
($H = 1, bf = 3$)