COSC 460 Databases
Midterm Exam 2 (Practice Version)
Fall 2018

This is was intended to be a practice exam... but it ended up being more of a study guide with a potpourri of questions. Nevertheless, you can expect the format of the second midterm to be similar to the format of the first (multiple choice, short answer, longer problems).

It is **different** from the real exam in several respects:

- The exam may have different questions and different parts per question. Nevertheless, this practice exam covers many of the topics you will see on the exam.
- There's no space to write your answers... the real exam will have space.
- I didn't assign points to questions (since each question has extra parts, the point totals wouldn't be accurate anyway).

Be sure to also review the recent homeworks. Similar questions may show up on the exam!

Question	Points	Score
1	0	
2	0	
3	0	
4	0	
5	0	
6	0	
7	0	
Total:	0	

1. Circle your answer.

   (a) Be sure to review questions from first practice exam, especially those about file organization and relational algebra.

   (b) With extendible hashing, overflow is impossible.

   ◯ True ◯ False

   (c) The leaves of a B+tree are arranged sequentially on disk.

   ◯ True ◯ False

   (d) Given a B+tree index on the Emp table with composite search key $\langle age, dno \rangle$, it is possible to evaluate the following query using only the index:

```
SELECT   E.dno, COUNT (*)
FROM     Emp E
WHERE    E.age=30
GROUP BY E.dno
```

   ◯ True ◯ False

   (e) Suppose you have a unclustered hash index on the Emp table with composite search key $\langle age, dno \rangle$. Consider the following query

```
SELECT   *
FROM     Emp E
WHERE    E.age=30
```

   It would be more efficient to answer this query using the index than simply doing a file scan. ◯ True ◯ False

   (f) To support range queries on two different search keys, the recommended practice is to construct a clustered index (data entry alternative 1) for each key.

   ◯ True ◯ False

   (g) Circle the query descriptions below for which using a *clustered* B+tree index instead of an *unclustered* B+tree index would noticeably improve performance.

      A. A range query over a reasonably large range (e.g. $3.6 < Student.gpa < 4.0$)

      B. An equality selection on a key field (e.g. $Student.sid = 1001$)

      C. An equality selection on a field with many duplicate values (e.g. $Apply.major =' Econ'$)

2. For each question, provide a short (2-3 sentences) answer.

   (a) Suppose that you are building a DBMS and want to add a new aggregate operator called TOPK, which is a variation of the MAX operator, and it returns the k largest items where k is an input given "at runtime." Explain how you would implement this operator as efficiently as possible, assuming that no indexes are defined over the input relation. Your answer may depend on k (i.e., you may do different things depending the value of k). Describe the cost in terms of a relation with N pages and p tuples per page and M frames in buffer pool.

   (b) Consider the same scenario as Part a but now assume you can create an unclustered B+Tree index. Explain how you would implement this operator.

   (c) Why are sequential page reads faster than random page reads?

   (d) What is pipelining and why is it important?

   (e) Give a concrete example of a relational algebra query plan where pipelining results lowers overall cost. Briefly explain your answer.

   (f) Give a concrete example of a relational algebra query plan where materializing some results may lower overall cost. Briefly explain your answer.

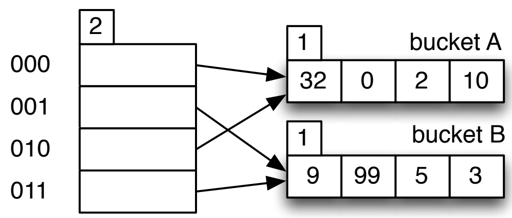
3. Hashing

   (a) Given an extendible hash index, if you insert a record and then delete it, the resulting index will be identical in structure and content as the index prior to the insertion.

   ◯ True ◯ False

   (b) What are the advantages of an extendible hash index over a static hash index?

   (c) Consider the following dynamic hash index. Suppose that the bucket capacity is 4 and the hashcode is $h(k) = k$.



   What is the *maximum* number of entry insertions that will cause the directory in this index to double? Give one such possible sequence of insertions of maximum length.

   (d) Show the resulting hash index.

   (e) Assume that when a bucket overflows, it continues to be split until it is no longer overflowing. Draw an extendible hashing index such that insertion of a data entry with hashed key value of 1 causes the directory to double *twice*. Show the local depth of each bucket and the global depth of the directory in your sketch.

4. SQL

Consider the following relational schema about a social network centered around college students and alumni. People can be friends, post messages, and like each other's messages. The year attribute in Users refers to the year of graduation.

```
Users(uid, name, school, year)
Friends(uid1, uid2)
Posts(pid, uid, text, datetime)
Likes(uid, pid, datetime)
```

If two users with ids 123 and 456 are friends, then (123, 456) and (456, 123) will both appear in the Friends relation.

For each of the following, write a **SQL query** that produces the desired information.

(a) For each post *author*, the name of the author along with the total number of likes they have received *across all of their posts*. Name this attribute `totalLikes`.

(b) For each post *author*, the maximum number of likes they have received *across all of their posts*. Name this attribute `maxLikes`.

(c) Find schools with at least 10 students. Avoid duplicates.

(d) Find names of users that have no friends. Avoid duplicates.

(e) Write a query that returns persons who have more distinct likers than friends. Alice is a "liker" of Bob if she likes one of Bob's posts.

(f) Write a query that returns the Colgate graduating class that has the most friends.

(g) Write a query that returns the names of "Colgate enemies": people who went to Cornell and have no Colgate friends (hint: they are not contained in set of friends of Colgate people).

(h) Write a query that returns the names of "Colgate friendlies": people who did not go to Colgate but have at least two friends that did.

(i) Write a query that returns the names of friends of President Casey's friends.

5. Comparing access methods. In this course you have learned about a number of structures for storing data: heapfiles, sorted files, clustered files, B-trees, dynamic hash indexes, static hash indexes, etc. No single structure is universally better than others: each structure is good for some access patterns and not so good for others. In the following, you are asked to compare two structures and describe a scenario in which one structure would be preferred to the other.

   For example: if asked when a heapfile would be preferred to a B+-tree, you might say that a heapfile would be preferred if the relation changes a lot (many inserts/deletes) but is not queried often (few searches).

   (a) You should be able to derive any of the expressions that characterize the the cost of various operations on the different types of files and indexes. (See the summary slide in lecture 9.)

   (b) Suppose you are interested in supporting range queries on a particular attribute. Describe a scenario in which a sequential scan on a heapfile could be faster than a search on an unclustered B+-tree.

   (c) When would a dynamic hash be preferred to a B+-tree?

   (d) Suppose you want to support fast range queries on a particular attribute of relation R. In addition, R is *static* meaning that it does not change (no insertions or deletions). Explain why a sorted file might be preferred to an unclustered B+-tree.

   (e) When would a static hash index be preferred to a dynamic hash index?

6. New data structures

   (a) Suppose you want to efficiently support queries of the following form:

   ```
   select sum(A) from R where v1 < R.B and R.B < v2
   ```

   where $v1$ and $v2$ are values supplied at runtime – i.e., the same query is invoked repeatedly with different values for $v1$ and $v2$. Describe how one could store extra information in the internal nodes of a B+-tree index on $R.B$ to efficiently compute the above sum.

   (b) Our description of static hashing implicitly assumed that there was a way to immediately retrieve the first page of bucket i for any $i = 0 \dots N-1$. But how would this actually happen in practice? Briefly sketch how to implement a static hash table. You can assume that you can ask the disk manager for a contiguous sequence of up to C pages but your solution must work even if the number of pages you need exceeds C. Access to a block should still be efficient.

7. Assume you have two relations R and S. Let N_R and N_S denote the number of pages in R and S respectively. Similarly, n_R and n_S denote the respective number of tuples. Let M denote the number of buffer pages.

   (a) For each of the following join algorithms, give the most general expression for the cost of performing $R \bowtie S$ in terms of the variables denoted above. If the cost is based on any assumptions, state those explicitly.

i. Nested loops

ii. Block nested loops

iii. Index nested loops

iv. Hash join

v. Sort-merge join

(b) Suppose R is much larger than S. How many buffer pages do you need to perform the sort-merge join with a cost of $3*(N_R+N_S))$? Give an expression for M in terms of the variables above. Explain your answer, including any assumptions made.

(c) Describe an algorithm for eliminating duplicates from R.

(d) Describe an algorithm for performing $R \cup S$.

(e) Describe an algorithm for performing $R \cap S$.

(f) Describe an algorithm for performing $R - S$.

(g) Reconsider parts (d)-(f) under bag semantics (i.e., duplicates permitted). For instance $R - S$ under bag semantics is as follows: suppose R has x copies of some tuple t and S has y copies the relation $R - S$ has $\max(0, x - y)$ copies of t in it.