CS 5/7330
Fall 2021
Homework 1

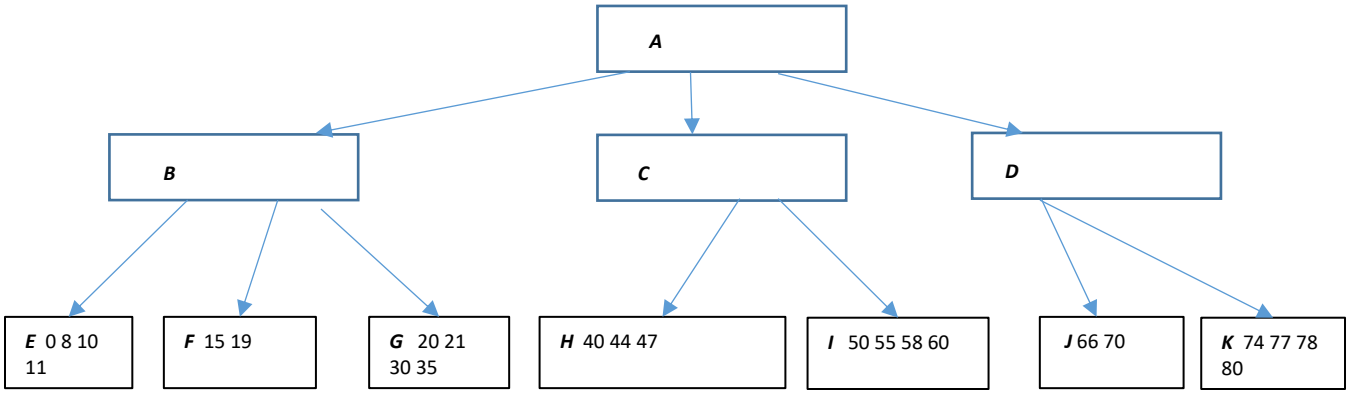
Due: Oct 14th (Thu) 11:59pm. (Late deadline: Oct 16th (Sat), 11:59pm)

1. (20 points) Consider building a B+-tree to store numbers. You are given the following constraints on the B+-tree.
    - Each leaf node can store at most 4 numbers
    - Each internal node can store at most 2 numbers (how many children maximum?)
    - Suppose an internal node stores (14, 28). The three children correspond to number with value strictly less than 14, greater than or equal 14 and strictly less than 28, and greater than or equal to 28 respectively.
    - If a node is split, and the number of items of the nodes are odd – this implies one of the split node will have one more item then the other. In such case choose the node on the "right" (containing larger numbers) to be the one who get one more item.

    a. Suppose 75 is inserted into the tree. This will cause nodeK to be split. That means a new key value need to be installed into node D. What is (in theory) the range of the value that can be used there? Explain your answer. (Notice that even though the algorithm use a certain number, but in theory there are other numbers that can be used without violating the B+=-tree's requirements).

    b. Fill in the key values of all nodes A to D, assuming we take the largest possible value for each key value. (Assume the insertion of 75 in part (a) did not happen).

    c. (Ignore part a) Suppose the following numbers are inserted (in order): 75, 48, 49, 2, 28. Every time a node is split, listed the contents of all the nodes being affected. Use the following convention:
        - For any leaf nodes that has changes, list its content after the insertion
        - If a node is split, name the two new nodes by added letter A and B to it. For example, if node K is split, the two new nodes should be named KA and KB. Later if KB is split, then the two nodes should be named KBA and KBB etc.
        - If a new root is created, name the new root N. If subsequently another new root is created then name it NN etc.



For example, for the case of 75:

- 75 is inserted to node J
  - Node K is spitted. New values for KA (74 75), KB (77, 78, 80)
  - Node D is affected. New value of D is (…..) [fill it in yourself]
- 48 is inserted to node …… (to be continued by you)

2. (20 points) Consider you have a Person table with *SSN* as the primary key, and an attribute *age* (there are other attributes, which is not important to this problem). You are also given the following:

- Each tuple of the table has size of 200 bytes
- Each sector (page) on the disk have 1600 bytes
- No tuple is split between two pages
- There are 250,000 tuples in the table
- The table is store in a single file, but is split (equally) between 2 tracks on the disk. Within the same track the sector of the file is contiguous
- Each seek/rotation combination takes 50 milliseconds on average
- Transferring a single page from the disk to memory take 0.5 millisecond.
- When you first access a file, you will need to do a single seek/rotation combination

a. How many tuples can be stored in a single page?
b. How many pages are needed to store the table?
c. Consider the following SQL query: SELECT * from Person where SSN="123456789". Calculate the *best case* and *worst case* time taken to answer this query if
   i. There is no index
   ii. There is a clustering index on SSN (Ignore the time needed for reading the index)
d. Now consider the following SQL query: SELECT * FROM Person WHERE (age > 20) and (age < 29) ORDER BY age. Assume that there is a non-clustering index on the age

attribute. Assume that you want to use the index to answer the query by first accessing the indexing, and then read each tuple *in the order that the index provided*. (Assume there is NO buffer to store the location of the buffer so as to make reading easier – i.e. you really do have to access each tuple in the order of the age attribute). Calculate the (worst case) time taken to answer this query using the index if

i. There are 2 tuples that satisfy this query
ii. There are 10,000 tuples that satisfy this query

(Once again, ignore the time needed for reading the index)

Show your work in all the cases.

3. (20 points) Consider using MongoDB to store the following information.

"We want to store teachers, classes textbooks, and publishers. For each teacher, we store his/her name (assume unique for this application) and his/her age. For each class, we store its class number (e.g. CS 5330). For each textbook (assume unique), we store its name and authors (maybe more than one authors). For each publishers, we only store their (unique) name.

Each textbook is published by one publisher. However each publisher publishes many textbooks. Each class can be taught by many teachers. For each teacher, he/she will choose a textbook for the class. Notice that for each class, each teacher will choose one textbook (those may be the same or different among different teachers). A textbook can be used by different classes and by different teachers. A teachers can also teach many classes.

You are given the following data. Represent them in the MongoDB data model. List all the documents in JSON format.

There are three teachers: John (age 26), Jane (age 28), Brad (age 30)
There are two classes : CS101, CS202
There are two publishers, P1, P2
There are three textbooks: T1, written by Johnson, published by P1; T2 written by Jackson and Hanson, published by P1; T3 written by Manson, published by P2.

Both John and Jane teaches CS 101. John would use T1, Jane will use T2 for this class
All three teachers teaches CS 102. John would use T2, Jane will use T3 and Brad will use T1 for this class