CS 430 Database Systems
Sample Assignment on B+ Trees 5

1. Consider the B+ tree index of order $d = 2$ shown in Figure 1. The leaf nodes are doubly linked. Each leaf node also points to the data blocks (not shown).

Answer the following questions.

(a) Show the tree that would result from inserting a data entry with key 9 into this tree.

(b) Show the B+ tree that would result from inserting a data entry with key 3 into the original tree.
(c) Show the B+ tree that would result from deleting the data entry with key 8 from the original tree, assuming that the left sibling is checked for possible redistribution.

(d) Show the B+ tree that would result from deleting the data entry with key 8 from the original tree, assuming that the right sibling is checked for possible redistribution.

(e) Show the B+ tree that would result from deleting the data entry with key 8 from the original tree, inserting a data entry with key 46 and then deleting the data entry with key 52.

(f) Show the B+ tree that would result from deleting the data entry with key 91 from the original tree.

(g) Show the B+ tree that would result from inserting a data entry with key 59, and then deleting the data entry with key 91.

(h) Show the B+ tree that would result from successively deleting the data entries with keys 32, 39, 41, 45, 73.

2. Consider the B+ tree index of order \( d = 2 \) shown in Figure 2. Each intermediate node can hold up to five pointers and four key values. Each leaf can hold up to four records, and leaf nodes are doubly linked as usual, although these links are not shown in the figure. The leaf nodes also point to the data blocks which are not shown.

Answer the following questions.

(a) Name all the tree nodes that must be fetched to answer the following query: Get all records with search key greater than 38.

(b) Insert a record with search key 109 into the tree.

(c) Delete the record with search key 81 from the original tree.

(d) Name a search key value such that inserting it into the original tree would cause an increase in the height of the tree.

(e) How would the answers to the above questions change if this were an indexed sequential file?

(f) Suppose this is a index sequential file. What is the minimum number of insertions needed to create a chain of three overflow pages?

3. Suppose that a page can contain at most four data values and that all data values are integers. Using only B+ trees of order 2, give examples of each of the following:
(a) A B+ tree whose height changes from 2 to 3 when the value 25 is inserted. Show your structure before and after the insertion.

(b) A B+ tree in which the deletion of the value 25 leads to redistribution. Show your structure before and after the deletion.

(c) A B+ tree in which the deletion of value 25 causes a merge of two nodes, but without changing the height of the tree.

4. Consider the B+ tree shown in Figure 3.

(a) Identify a list of five data entries such that:
   i. Inserting the entries in the order shown and then deleting them in the opposite order (e.g. insert a, insert b, delete b, delete a) results in the original tree.
   ii. Inserting the entries in the order shown and then deleting them in the opposite order (e.g. insert a, insert b, delete b, delete a) results in a different tree.

(b) What is the minimum number of insertions of data entries with distinct keys that will cause the height of the original tree to change from its current value (of 1) to 3?
Figure 3: Figure for Question 3