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Devoir 7 (2.5% - 10 points)
CSI2110/CSI2510 (Automne 2022)

Question 1.

In the (2,4)-tree, at most 4 children's nodes that are either 2, 3, or 4. The external nodes should have the same depth.

Drawing (2,4)-tree:

Insert key 5 which is the root node.

Insert the key 16 then the root node becomes (5, 16)

Insert the key 20 which is also inserted at the root node and the node becomes (5, 16, 20).

After inserting key 45, key 16 becomes the root node. The left child of key 16 is 5 and the right child is (20, 45).

Insert key 2 which is smaller than the root node 16 therefore insert at the left tree. Hence the left child of the root node 16 is (2, 5).

Now root node is 16: left child (2, 5) and right child(20, 45).

Insert key 10 which is smaller than root 16, therefore which is inserted to the left of 16.

Now root node is 16: left child(2, 5, 10) and right child(20, 45).

Insert the key 18 which is greater than root node 16 therefore, this key should e inserted to the right of 16.

Now root node is 16: left child(2, 5, 10) and right child(18, 20, 45).

Insert the key 30 into the tree to the right of root node 16 because it is greater than the root node.

After inserting the key 30, the right tree becomes (30, 45).

The key is 18 becomes the middle child after the left tree.

Now root node is 16: left child or first(2, 5, 10), the second child(after the left child) 18, and the right child or third child (20, 45).

Insert the key 50 which is greater than the root node 16 hence this key becomes the right child.

Therefore, the root node is 16: left child or first(2, 5, 10), the second child(after the left child) 18, and the right child or third child (20, 45, 50).

Insert key 12 into the left child of root node 16 because it is smaller than the root node.

After inserting the key 12, the root node becomes (5, 16, 20), left child 2, the middle child (10, 12), next middle child 18, and the right child (30, 45, 50).

Insert the last key 1. After inserting the left child will become (1, 2)

Therefore, the tree is as follows in order:

Root node: (5, 16, 20)

Leftmost child or first child: (1, 2)

second child: (10, 12)
Third child: 18
Rightmost child or fourth child: (30, 45, 50)

Question 2

A 2-4 tree is a kind of multi-way search tree that also has the following two properties:

Every node in the tree can have at most 4 children.
All the external nodes in the tree have the same depth

Delete key 4:

If key 4 is removed from the given tree, the depth of all external nodes doesn't remain the same as node 5 will have no children as shown below:

```
              5  12

               |  \

              7     15
```

Now to maintain the same depth, modify the tree so that the properties of 2-4 tree are maintained. Modify the tree by making the key 12 as root and merging the 5 and 12 as shown below:

```
                 12

                /   \

             5, 7     15
```

Delete key 15:

Again on deleting the key 15, the depth of external nodes doesn't remain the same as the 12 has no right children as shown below:

```
                 12

                 /
```

<center>5, 7</center>

Now to maintain the same depth, modify the tree so that the properties of 2-4 tree are maintained. Modify the tree by making the key 7 as the root and making 5 the left child and 12 the right child as shown below:

```
            7
           / \
          5   12
```

Delete key 5:

Again on deleting the key 5, the depth of external nodes doesn't remain the same as the 7 has no left children as shown below:

```
            7
             \
             12
```

Now to maintain the same depth, modify the tree so that the properties of 2-4 tree are maintained. Modify the tree by making the keys 7, and 12 the root as shown below:

<center>7, 12</center>