CS3310 Data and File Structures with Java
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Assignment: 5

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Software Life Cycle Report – Assignment 5

Phase 1: Specification

- Practice building B trees
- Practice searching B trees
- Develop high-performance solutions

Program Output is at the end of this file.

Phase 2 Design:

Modules and Basic structure

Module 1: Class Main

Fields:

1. Final int ASCII_LENGTH – number of ascii values to generate
2. Characters characters[] – holds the characters
3. Int decimal[] – holds the decimals
4. String octal[] – holds the octal values as strings
5. String hex[] – holds the hex values as strings
6. Tree23 – a tree is made for each value
7. Tree234 – a tree is made for each value
8. Long total[] – holds the total time for 2-3 and 2-3-4 trees

Methods:

1. Int getSearchValue() – receives the search value from the user
2. Long[] searchBothTrees(8 binary trees) – main search manager for searching the trees for the given value from the user
3. Long[] Search(4 b trees) – perform the actual search of the b trees
4. Long[] search(4 b trees) – perform the actual search for the 2-3 trees
5. Integer[] getValue(String) – converts the given value to searchable values
6. writeFiles(8 binary trees) – writes the level traversal to files
7. writeAverage(long[]) – writes the average search time to the console

8.

Module 2: LeafNode

Fields:

1. private Key ldata – only used on actual leaf nodes
2. private Key lkey – largest value in the left subtree
3. private Key rkey – largest value in the middle subtree
4. private LeafNode<Key> parent – pointer to the parent node
5. private LeafNode<Key>lNode – pointer to the left node
6. private LeafNode<Key>mNode – pointer to the middle node
7. private LeafNode<Key>rNode – pointer to the right node
8. boolean isLeaf – if the node is being inserted as a leaf or internal node

Methods:

1. Standard getters and setters for the fields

Module 3: LeafNode234

Fields:

1. Private Key ldata – only used in leaf nodes
2. Private key lkey – largest value in left subtree
3. Private key mkey – largest value in the middle left subtree
4. Private key rkey – largest value in the middle right subtree
5. Private LeafNode234<Key> parent – pointer to the parent node
6. Private LeafNode234<Key> lNode – pointer to the left subtree
7. Private LeafNode234<Key> M0Node – pointer to the middle left subtree
8. Private LeafNode234<Key> mNode – pointer to the middle right subtree
9. Private LeafNode234<Key> rNode – pointer to the right subtree
10. Boolean isLeaf – if the node is being inserted as a leaf or internal node

Methods:

1. Standard getters and setters for the fields

Module 4: NodeQueue23

Fields:

1. NodeQueue23<Key> next – pointer to the next item in the list
2. LeafNode<Key> data – B Tree node held

Methods

1. Standard getters and setters for the fields

Module 5: NodeQueue234
Fields:
1. Private NodeQueue234<Key> next – pointer to the next item in the list
2. Private LeafNode234<Key> data – B Tree node held

Methods:
1. Standard getters and setters for the fields

Module 6: Queue23
Fields:
1. Private NodeQueue next – the next Node in the queue
2. Private Node data – the data held

Methods:
1. Getters and setters for the fields

Module 7: Queue23
Fields:
1. Private NodeQueue23<Key> head – the head node to the queue
2. Private NodeQueue23<Key> tail – the tail node to the queue

Methods:
1. Getters and setters for the fields
2. Void add(LeafNode<Key> newNode) – adds the new Node to the end of the queue
3. NodeQueue23<Key> delete() – deletes the head node of the queue

Module 8: Queue234
Fields:
1. Private NodeQueue234<Key> head – the head node to the queue
2. Private NodeQueue234<Key> tail – the tail node to the queue

Methods:
1. Getters and setters for the fields
2. Void add(LeafNode234<Key> newNode) – adds the new Node to the end of the queue
3. NodeQueue234<Key> delete() – deletes the head node of the queue

Modele 9: Tree23
Fields:
1. LeafNode<Key> root – root of the tree

Methods:
1. Void insert(LeafNode<Key> current, LeafNode<Key> newNode) – insert a new node into the tree – either leaf node or internal node

2. LeafNode<Key> search(LeafNode<Key> current, LeafNode<Key> newNode) – finds the parent node to add the new node to
3. Int addNode(LeafNode<Key> parent, LeafNode<Key> newNode) – attempts to add the new node to the parent node. 0 is return on failure
4. Int add(LeafNode<Key> current, LeafNode<Key> newNode) – attemps to add the new leaf node to the parent node. 0 is returned on failure
5. Void split(LeafNode<Key parent, LeafNode<Key> newNode) – takes the newNode and adds it to the newly created, split node
6. Void makeNewRoot(LeafNode<Key> left, LeafNode<Key> right) – used to split the root node
7. Void printInOrder(LeafNode<Key> current) – prints the tree with an in-order traversal
8. Key search(LeafNode<Key> current, Key value) – searches the tree for the given value – null is returned if the value is not found
9. Void traversal(FileWriter file) – performs a level traversal and writes the data to the given file

Module 10 – Tree234

Same information as Tree23

1. Method – void setKeys(LeafNode<Key> parent) – sets the keys of the given parent node

Pseudocode
Class - Main

```
Main()
    Make a variable to determine the number of ascii values to generate
    Make 4 arrays to hold the generated ascii values
    Run a for loop to generate the ascii values
        Use Integer.toOctalString and Integer.toHexString to convert the decimal values to octal and hex string representations
        Save the values to the appropriate arrays
    Make 4 variables to hold the 4 2-3 Binary Trees
    Run a for loop to insert the given ascii values to the appropriate B Tree
        Call the B Tree object.insert() method
    Make 4 variables to hold the 4 2-3-4 Binary Trees
    Run a for loop to insert the given ascii values to the appropriate B Tree
```

```
        Call the B Tree object.insert() method

    Write the level traversal to files with writeFiles()
    Allow the user to search for values with searchBothTrees()
    Print the average serach time with writeAverage()

getSearchValue()
    Make a variable to hold the user input
    Make a boolean to determine if good input was given
    Use a while loop to continue to prompt for data until good data in given
        Use a try catch to catch an error thrown
            Use the global scanner object to retrieve input from the user
            Throw an error if no input is given
        Catch the error
            Tell the user that no input was given and re prompt for input

searchBothTrees()
    Make a variable and call the getSearchValue() to get the value the user wants to search for
    Make an array to hold the total search time and number of searches for both data structures
    Run a while loop until the user inputs quit
        Create a temporary array to hold the runtime and count for the individual B Tree
        Search the B tree by calling search23()
        Add the temp array to the total time and total count
        Search the 2-3-4 tree by calling search()
        Add the temp array to the total time and total count for the 2-3-4 tree
        Prompt the user for more input by calling getSearchValue()
Search()
    Initialize variables to hold the converted input data to Decimal, octal, hex, and char
    Initialize variables to hold the total run time
    Search for the decimal value of the input
        Call search on hex, octal, and char to get the information for the given decimal
    Search for the hex value
        Call search on decimal,  octal, and char to get the information for the given hex
    Search for the octal value
        Call search on the octal, hex, and char to get the information for the given octal
    Search for the char value
        Call search on the decimal, octal, and hex to get the information for the given char
    Return the total time spent searching and the total searches

Search234()
    Same as search(), but performed on the 2-3-4 B Tree

getValues()
    Converts the given string input to the needed decimal, octal, hex, and char
    Null is set if the string cannot be converted to the given value
    If statements are used to catch values of chars that cannot be typed
writeFiles()
    Create 8 files to write to
    Create 8 WriteFile objects to write to the given files
    Call the traversal() method for each Tree to print the level traversals to the files
    Close the files
writeAverage()
    Write the average search time to the console for the given 2-3 and 2-3-4 Tree
```

Class – Queue23 and Queue234

```
Standard getters and setters
Add()
    Create a new node with the given data
    Add the new node to the tail of the queue
Delete()
    Delete a node from the queue and return it
```

Class – Tree23

```
Insert()
    If the node being inserted is a leaf node
        If the root is null
            Create a new node and set it as root
        If root is a leaf node
            Create a new node and add the two nodes to it
            Set the new node as the root
        IF the root is not a leaf node
            Call search() to find the parent node to add the new node to
            Call add() to add the new node to the parent
            If the parent doesn't have space for the new node
                Call split()
    If the new node is not a leaf node
        Call addNode() to insert the new tree into the main tree
        If error is returned
            Call split to make room
Search()
    Base case – we are at the leaf nodes, return the parent of the leaf node
    Otherwise move through the B Tree accordingly
        If the new node is less than the left key – move left
        If the new node is less than the right key – move to the middle
        Else move to the right

addNode() – used for adding a subtree
    if either of the middle or right nodes are null, then we have a spot to add
the new node
        determine which spot the new node should be in and move the keys
and node pointers accordingly
    else
        return an error so split() can be called

add()
    if either of the middle or right nodes are null, then we have a spot to add
the new node
        Determine the spot to add the new node and move the keys and
node pointers accordingly
```

```
    Else
        Return an error so split() can be called

Split()
    Split the left node into 2 nodes
    Create a new node
    Add the left node’s right child to the left of the new node
    Add the node to be inserted into the middle of the new node
    Set the keys accordingly
    Set the right subchild of the left node to null as the child was moved
    If the left node was the root node, then the new node cannot be added to its parent
        Call makeNewRoot()
    Else
        Re insert the new node into the parent of the left node
makeNewRoot()
    Take in the left and right subtrees
    Make a new root node
    Set the left child to be the left subtree and middle child to be the right subtree
    Set the keys accordingly
    Set root as the new root

Search()
    Base case – current node is null, return null
    Base case – current value is a leaf node
        If it equals the searched value then return the value
        Else return null
    Otherwise move down the tree
        If value is less the left key, move left
        If the value is less than the right key, move to the middle
        Else move to the right

Traversal()
    Create a queue object to add the nodes to
    Call list.add(root) to add all the nodes to the queue
    Use a while loop that stops when there are no more nodes in the queue
```

Remove an object from the queue – print its data

Class – Tree234

Methods are the same as Tree23, but the middle keys must be checked when traversing

When nodes are split, the left node will have 3 children and the new right node will have 2 children

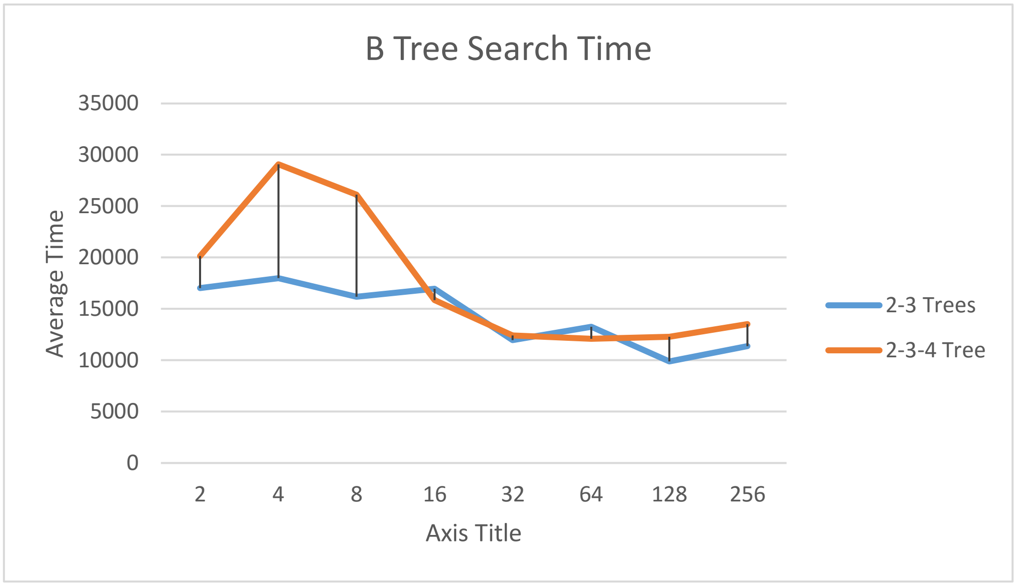
Class: LeafNode, LeafNode234, NodeQueue23, NodeQueue234

These classes only has standard getters and setters for the fields

Summary Analysis

The binary trees allow for quick searching on many records. The 2-3 Tree can have up to log base 3 height with a minimum of log base 2 height. The 2-3-4 Tree can have as many as log 2 height, if all nodes had 2 children, or as few as log base 4 height. For my implementation, I used 128 ascii values as the searchable range. This allows for 5-7 as the height for the 2-3 tree and 4-7 as the height for the 2-3-4 tree. The number of leaves for both the trees will be the same as the leaves are the records being added.

One of the main differences in the 2-3 tree and the 2-3-4 tree is the requirement for an addition key in the 2-3-4 tree. This means that when adding a new node more values must be checked and eventually moved to keep the sorting the tree offers. It also means that when a node is split that either the left node can have 3 children and the right 2 or the the left can have 2 and the right 3. This would be determined on how the data would be added to the tree, either close to in-order or reverse-order.



Time Complexity

Main

Main – adds the nodes to the tree O(n)

Tree

insert – O(h)

search – O(h)

addNode – O(1)

add – O(1)

split – O(1)

makeNewRoot – O(1)

search for value – O(h)

traversal – O(n)

Time complexity is difficult to measure with such a small table as the ascii table. The searching is performed very quickly as the trees only have a few levels the pass through. This brings variability into the consistency of the computer running the application. I kept the computer as consistent as possible for the search to have the best outcome. Over a large data set, the 2-3-4 tree would start to show the signs of faster searching as it would have less levels.

Phase 3: Risk Analysis

The traversal files are overwritten each time the program is run. This may cause data loss of previous runs if the user is not careful.

Phase 4: Verification

I searched for multiple values many times.

Phase 5: Coding

The code of this program is included in the zip file. The code is explained with comments and line breaks to make reading easier. A Javadoc is also made to explain the use of each method.

Phase 6: Testing

Tree traversals were output as files.

Phase 7: Refining the program

Refinements can be made after the client has used the application

Phase 8: Production

A zip file including the source files from eclipse and the output of the program have been included.

Phase 9: Maintenance

Changes can be made once feedback is received.