Practical = 7

Name: shubham shivraj Suryawanshi
Reg. No: 2020BIT004

Write a code with complete simulation of the following
AVL tree
Binary Heap
Max Heap
Min Heap
Heapyfy

1) AVL tree

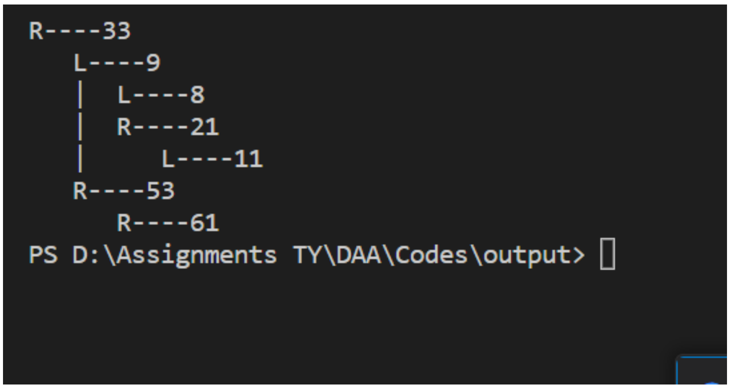
AVL tree implementation in C++

```
#include <iostream>
using namespace std;

class Node {
   public:
  int key;
  Node *left;
  Node *right;
  int height;
};

int max(int a, int b);

// Calculate height
int height(Node *N) {
  if (N == NULL)
    return 0;
  return N->height;
}

int max(int a, int b) {
  return (a > b) ? a : b;
}

// New node creation
Node *newNode(int key) {
  Node *node = new Node();
  node->key = key;
  node->left = NULL;
  node->right = NULL;
  node->height = 1;
  return (node);
}

// Rotate right
Node *rightRotate(Node *y) {
  Node *x = y->left;
  Node *T2 = x->right;
  x->right = y;
  y->left = T2;
  y->height = max(height(y->left),
          height(y->right)) +
        1;
  x->height = max(height(x->left),
          height(x->right)) +
        1;
  return x;
```

```
}

// Rotate left
Node *leftRotate(Node *x) {
  Node *y = x->right;
  Node *T2 = y->left;
  y->left = x;
  x->right = T2;
  x->height = max(height(x->left),
          height(x->right)) +
        1;
  y->height = max(height(y->left),
          height(y->right)) +
        1;
  return y;
}

// Get the balance factor of each node
int getBalanceFactor(Node *N) {
  if (N == NULL)
    return 0;
  return height(N->left) -
       height(N->right);
}

// Insert a node
Node *insertNode(Node *node, int key) {
  // Find the correct postion and insert the node
  if (node == NULL)
    return (newNode(key));
  if (key < node->key)
    node->left = insertNode(node->left, key);
  else if (key > node->key)
    node->right = insertNode(node->right, key);
  else
    return node;

  // Update the balance factor of each node and
  // balance the tree
  node->height = 1 + max(height(node->left),
             height(node->right));
  int balanceFactor = getBalanceFactor(node);
  if (balanceFactor > 1) {
    if (key < node->left->key) {
      return rightRotate(node);
    } else if (key > node->left->key) {
      node->left = leftRotate(node->left);
      return rightRotate(node);
    }
  }
  if (balanceFactor < -1) {
    if (key > node->right->key) {
      return leftRotate(node);
    } else if (key < node->right->key) {
      node->right = rightRotate(node->right);
      return leftRotate(node);
    }
  }
  return node;
}

// Node with minimum value
Node *nodeWithMimumValue(Node *node) {
  Node *current = node;
  while (current->left != NULL)
    current = current->left;
  return current;
}
```

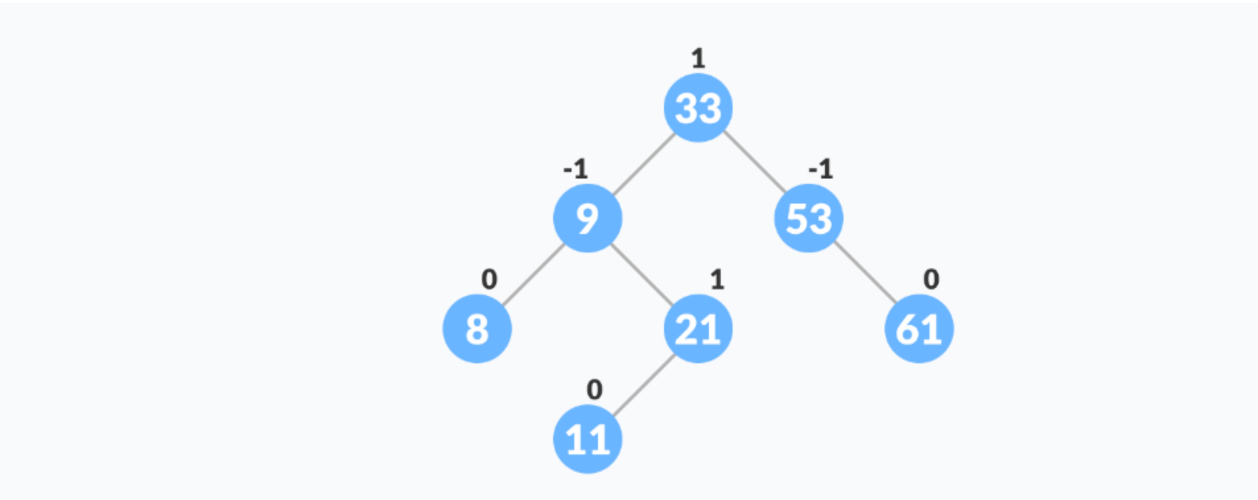
```
// Delete a node
Node *deleteNode(Node *root, int key) {
  // Find the node and delete it
  if (root == NULL)
    return root;
  if (key < root->key)
    root->left = deleteNode(root->left, key);
  else if (key > root->key)
    root->right = deleteNode(root->right, key);
  else {
    if ((root->left == NULL) ||
      (root->right == NULL)) {
      Node *temp = root->left ? root->left : root->right;
      if (temp == NULL) {
        temp = root;
        root = NULL;
      } else
        *root = *temp;
      free(temp);
    } else {
      Node *temp = nodeWithMimumValue(root->right);
      root->key = temp->key;
      root->right = deleteNode(root->right,
               temp->key);
    }
  }

  if (root == NULL)
    return root;

  // Update the balance factor of each node and
  // balance the tree
  root->height = 1 + max(height(root->left),
             height(root->right));
  int balanceFactor = getBalanceFactor(root);
  if (balanceFactor > 1) {
    if (getBalanceFactor(root->left) >= 0) {
      return rightRotate(root);
    } else {
      root->left = leftRotate(root->left);
      return rightRotate(root);
    }
  }
  if (balanceFactor < -1) {
    if (getBalanceFactor(root->right) <= 0) {
      return leftRotate(root);
    } else {
      root->right = rightRotate(root->right);
      return leftRotate(root);
    }
  }
  return root;
}

// Print the tree
void printTree(Node *root, string indent, bool last) {
  if (root != nullptr) {
    cout << indent;
    if (last) {
      cout << "R----";
      indent += "   ";
    } else {
      cout << "L----";
      indent += "|  ";
    }
    cout << root->key << endl;
    printTree(root->left, indent, false);
```

```
    printTree(root->right, indent, true);
  }
}

int main() {
  Node *root = NULL;
  root = insertNode(root, 33);
  root = insertNode(root, 13);
  root = insertNode(root, 53);
  root = insertNode(root, 9);
  root = insertNode(root, 21);
  root = insertNode(root, 61);
  root = insertNode(root, 8);
  root = insertNode(root, 11);
  printTree(root, "", true);
  root = deleteNode(root, 13);
  cout << "After deleting " << endl;
  printTree(root, "", true);
}
```
Output:



```
R----33
   L----9
   |  L----8
   |  R----21
   |     L----11
   R----53
      R----61
PS D:\Assignments TY\DAA\Codes\output>
```

Simulation:



2) Binary Heap

```
// A C++ program to demonstrate common Binary Heap Operations
#include<iostream>
#include<climits>
using namespace std;

// Prototype of a utility function to swap two integers
void swap(int *x, int *y);

// A class for Min Heap
```

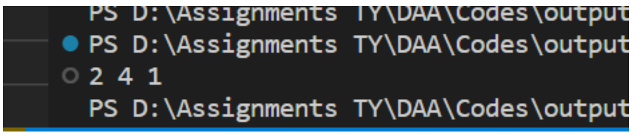
```
class MinHeap
{
	int *harr; // pointer to array of elements in heap
	int capacity; // maximum possible size of min heap
	int heap_size; // Current number of elements in min heap
public:
	// Constructor
	MinHeap(int capacity);

	// to heapify a subtree with the root at given index
	void MinHeapify(int );

	int parent(int i) { return (i-1)/2; }

	// to get index of left child of node at index i
	int left(int i) { return (2*i + 1); }

	// to get index of right child of node at index i
	int right(int i) { return (2*i + 2); }

	// to extract the root which is the minimum element
	int extractMin();

	// Decreases key value of key at index i to new_val
	void decreaseKey(int i, int new_val);

	// Returns the minimum key (key at root) from min heap
	int getMin() { return harr[0]; }

	// Deletes a key stored at index i
	void deleteKey(int i);

	// Inserts a new key 'k'
	void insertKey(int k);
};

// Constructor: Builds a heap from a given array a[] of given size
MinHeap::MinHeap(int cap)
{
	heap_size = 0;
	capacity = cap;
	harr = new int[cap];
```

```
}

// Inserts a new key 'k'
void MinHeap::insertKey(int k)
{
	if (heap_size == capacity)
	{
		cout << "\nOverflow: Could not insertKey\n";
		return;
	}

	// First insert the new key at the end
	heap_size++;
	int i = heap_size - 1;
	harr[i] = k;

	// Fix the min heap property if it is violated
	while (i != 0 && harr[parent(i)] > harr[i])
	{
	swap(&harr[i], &harr[parent(i)]);
	i = parent(i);
	}
}

// Decreases value of key at index 'i' to new_val. It is assumed that
// new_val is smaller than harr[i].
void MinHeap::decreaseKey(int i, int new_val)
{
	harr[i] = new_val;
	while (i != 0 && harr[parent(i)] > harr[i])
	{
	swap(&harr[i], &harr[parent(i)]);
	i = parent(i);
	}
}

// Method to remove minimum element (or root) from min heap
int MinHeap::extractMin()
{
	if (heap_size <= 0)
		return INT_MAX;
	if (heap_size == 1)
```

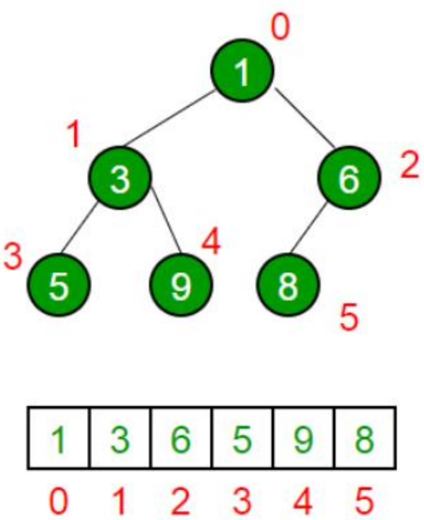
```
	{
		heap_size--;
		return harr[0];
	}

	// Store the minimum value, and remove it from heap
	int root = harr[0];
	harr[0] = harr[heap_size-1];
	heap_size--;
	MinHeapify(0);

	return root;
}


// This function deletes key at index i. It first reduced value to minus
// infinite, then calls extractMin()
void MinHeap::deleteKey(int i)
{
	decreaseKey(i, INT_MIN);
	extractMin();
}

// A recursive method to heapify a subtree with the root at given index
// This method assumes that the subtrees are already heapified
void MinHeap::MinHeapify(int i)
{
	int l = left(i);
	int r = right(i);
	int smallest = i;
	if (l < heap_size && harr[l] < harr[i])
		smallest = l;
	if (r < heap_size && harr[r] < harr[smallest])
		smallest = r;
	if (smallest != i)
	{
		swap(&harr[i], &harr[smallest]);
		MinHeapify(smallest);
	}
}

// A utility function to swap two elements
```

```
void swap(int *x, int *y)
{
        int temp = *x;
        *x = *y;
        *y = temp;
}

// Driver program to test above functions
int main()
{
        MinHeap h(11);
        h.insertKey(3);
        h.insertKey(2);
        h.deleteKey(1);
        h.insertKey(15);
        h.insertKey(5);
        h.insertKey(4);
        h.insertKey(45);
        cout << h.extractMin() << " ";
        cout << h.getMin() << " ";
        h.decreaseKey(2, 1);
        cout << h.getMin();
        return 0;
}}
```

Output:



Simulation:

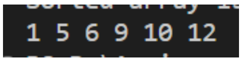


3) Max Heap

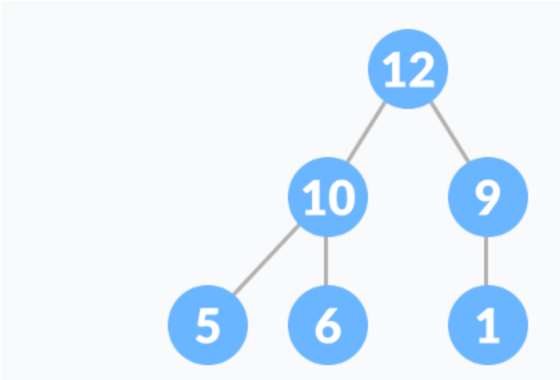
```
#include <iostream>
```

```
using namespace std;
 void heapify(int arr[], int n, int i) {
 // Find largest among root, left child and right child
 int largest = i;
 int left = 2 * i + 1;
 int right = 2 * i + 2;

 if (left < n && arr[left] > arr[largest])
   largest = left;

 if (right < n && arr[right] > arr[largest])
   largest = right;

 // Swap and continue heapifying if root is not largest
 if (largest != i) {
   swap(arr[i], arr[largest]);
   heapify(arr, n, largest);
 }
}

// main function to do heap sort
void heapSort(int arr[], int n) {
 // Build max heap
 for (int i = n / 2 - 1; i >= 0; i--)
   heapify(arr, n, i);

 // Heap sort
 for (int i = n - 1; i >= 0; i--) {
   swap(arr[0], arr[i]);

   // Heapify root element to get highest element at root again
   heapify(arr, i, 0);
 }
}

// Print an array
void printArray(int arr[], int n) {
 for (int i = 0; i < n; ++i)
   cout << arr[i] << " ";
 cout << "\n";
}

// Driver code
int main() {
 int arr[] = {1, 12, 9, 5, 6, 10};
```

```
    int n = sizeof(arr) / sizeof(arr[0]);
    heapSort(arr, n);

    cout << "Sorted array is \n";
    printArray(arr, n);
}
```
Output:-

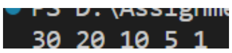

1 5 6 9 10 12

Simulation:



4) Min Heap

```
#include <bits/stdc++.h>
using namespace std;

// Driver code
int main ()
{
 // Creates a max heap
 priority_queue <int> pq;
 pq.push(5);
 pq.push(1);
 pq.push(10);
 pq.push(30);
 pq.push(20);

 // One by one extract items from max heap
 while (pq.empty() == false)
 {
         cout << pq.top() << " ";
         pq.pop();
 }

 return 0;
}
```
Output:-


30 20 10 5 1

Simulation:

```
            5                           13
         /      \                     /       \
      10          15               16           31
      /                           /  \         /  \
    30                          41    51     100   41
```

5)Heapyfy

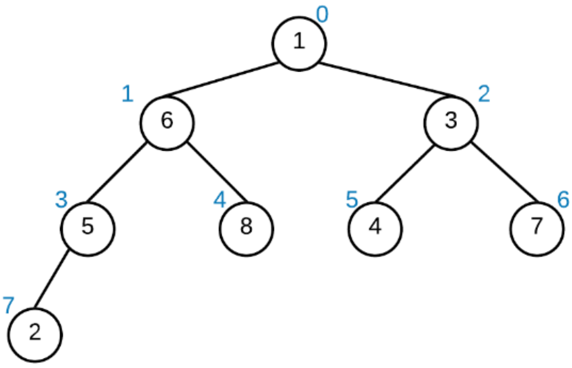
```
#include <iostream>
using namespace std;

// To heapify a subtree rooted with node i
// which is an index in arr[].
// n is size of heap
void heapify(int arr[], int N, int i)
{

 // Initialize largest as root
 int largest = i;

 // left = 2*i + 1
 int l = 2 * i + 1;

 // right = 2*i + 2
 int r = 2 * i + 2;

 // If left child is larger than root
 if (l < N && arr[l] > arr[largest])
 	largest = l;

 // If right child is larger than largest
 // so far
 if (r < N && arr[r] > arr[largest])
 	largest = r;

 // If largest is not root
 if (largest != i) {
 	swap(arr[i], arr[largest]);

 	// Recursively heapify the affected
 	// sub-tree
 	heapify(arr, N, largest);
```

```
 }
}

// Main function to do heap sort
void heapSort(int arr[], int N)
{

 // Build heap (rearrange array)
 for (int i = N / 2 - 1; i >= 0; i--)
 	heapify(arr, N, i);

 // One by one extract an element
 // from heap
 for (int i = N - 1; i > 0; i--) {

 	// Move current root to end
 	swap(arr[0], arr[i]);

 	// call max heapify on the reduced heap
 	heapify(arr, i, 0);
 }
}

// A utility function to print array of size n
void printArray(int arr[], int N)
{
 for (int i = 0; i < N; ++i)
 	cout << arr[i] << " ";
 cout << "\n";
}

// Driver's code
int main()
{
 int arr[] = { 12, 11, 13, 5, 6, 7 };
 int N = sizeof(arr) / sizeof(arr[0]);

 // Function call
 heapSort(arr, N);

 cout << "Sorted array is \n";
 printArray(arr, N);
}
```

Output:-

```
5 6 7 11 12 13
```

Simulation:



1	6	3	5	8	4	7	2
0	1	2	3	4	5	6	7