**Data Structures**

**Linked List**

**Sorted Merge:**

**Given two sorted linked lists merge them in place**.

struct node\* result = NULL;

  /\* Base cases \*/

  if (a == NULL)

     return(b);

  else if (b==NULL)

     return(a);

  /\* Pick either a or b, and recur \*/

  if (a->data <= b->data)

  {

     a->next = SortedMerge(a->next, b);

return a;

  }

  else

  {

     b->next = SortedMerge(a, b->next);

return b;

  }

**Floyd cycle detection proof:**  
Let x be the distance from the start of the loop. And y be the distance from loop start to point where 2 pointers meet and z be the remaining measurement of cycle.

Suppose fast pointer has run over ‘m’ cycles before meeting the slow pointer. ‘i’ is the distance travelled by slow pointer and ‘2i’ is covered by fast pointer.

We can write the equations as:

i = x + y

2i = x + m(y+z) + y

This gives us:

2\*(x + y) = x + m(y + z) + y

x = (m-1)(y+z) + z

Hence, if we keep slow pointer at x start moving it, fast pointer would have cycled ‘m-1’ times with meeting slow pointer right at loop beginning. The same can be used to find the point of loop start so as to remove the loop from the linked list.

/\* If loop exists \*/

    if (slow == fast)

    {

        slow = head;

        while (slow != fast->next)

        {

            slow = slow->next;

            fast = fast->next;

        }

        /\* since fast->next is the looping point \*/

        fast->next = NULL; /\* remove loop \*/

    }

To reverse a list after every ‘k’ nodes. Use recursion over complete list and loop for reversal of k nodes.

**Delete nodes which have a greater value on right side**

To delete nodes in linked list which has its larger element on right, reverse the linked list. Take max = head->data and start looping. If cur\_node > max then max = cur\_node else delete the node.

**To create a linked list in which children are 2\*i+1 and 2\*i+2**

Use queue and go for level order traversal while traversing through the list in parallel.

**Create BST from linked list**

Method 1:

* Get the middle of linked list, make it as root

Do

* root->left = createBST(0, mid-1); root->right = createBST(mid+1, n);

**Method 2:**

struct Node\* sortedListToBSTRecur(struct Node \*\*head\_ref, int n)

{

    /\* Base Case \*/

    if (n <= 0)

        return NULL;

    /\* Recursively construct the left subtree \*/

    struct Node \*left = sortedListToBSTRecur(head\_ref, n/2);

    /\* head\_ref now refers to middle node, make middle node as root of BST\*/

    struct Node \*root = \*head\_ref;

    // Set pointer to left subtree

    root->prev = left;

    /\* Change head pointer of Linked List for parent recursive calls \*/

    \*head\_ref = (\*head\_ref)->next;

    /\* Recursively construct the right subtree and link it with root

      The number of nodes in right subtree  is total nodes - nodes in

      left subtree - 1 (for root) \*/

    root->next = sortedListToBSTRecur(head\_ref, n-n/2-1);

    return root;

}

**To find a triplet in 2 list whose sum is equal to a given number:**

Let the lists be a, b and c. Sort ‘b’ in ascending order and ‘c’ in descending order . Start traversing a, while(a != NULL)

If(sum < requisite)

B=b->next

Else

C=c->next

**To flatten linked list having both right and down pointers. Recurse the merge by merging down lists of root and root->right**

// The main function that flattens a given linked list

Node\* flatten (Node\* root)

{

    // Base cases

    if (root == NULL || root->right == NULL)

        return root;

    // Merge this list with the list on right side

    return merge( root, flatten(root->right) );

}

**Flatten a multilevel linked list**

1) Take "cur" pointer, which will point to head of the fist level of the list

2) Take "tail" pointer, which will point to end of the first level of the list

3) Repeat the below procedure while "curr" is not NULL.

I) if current node has a child then

a) append this new child list to the "tail"

tail->next = cur->child

b) find the last node of new child list and update "tail"

tmp = cur->child;

while (tmp->next != NULL)

tmp = tmp->next;

tail = tmp;

II) move to the next node. i.e. cur = cur->next

**Sort list of 0’s, 1’s and 2’s**

**Approach 1:** Count number of 0, 1, and 2 and fill them**.**

**Approach 2 :** Segregate lists of 0, 1 and 2 and then merge them.

**Reverse alternate nodes and append to the end of list**

**Approach 1:** Separate the 2 lists. Reverse the 2nd and append to first.

**Approach 2:** Use a single loop to carry out the task. Below is the solution

while (odd && odd->next)

    {

       // Store the next node in odd list

       struct node \*temp = odd->next->next;

       // Link the next even node at the beginning of even list

       odd->next->next = even;

       even = odd->next;

       // Remove the even node from middle

       odd->next = temp;

       // Move odd to the next odd node

       if (temp != NULL)

         odd = temp;

    }

**To clone a linked list containing the random pointers**

**Approach 1:**

In this, first store the next pointer of the original list in array and point them to the corresponding element of the new linked list. Also, point the random pointer of new list to point to paralleled node of original list. After that do :

clone->arbit = clone->arbit->arbit->next;

And restore the original list after looking into the array.

**Approach 2:**

Add the cloned list in interleaved original list. After that, do:

original->next->arbitrary = original->arbitrary->next;

and restore:

original->next = original->next->next;

copy->next = copy->next->next;

**Approach 3:**

Another approach could be to maintain a hashmap of addresses of original and duplicated list. Traverse through the original list. Search its arbitrary pointer in O(1) time and point the arbitrary pointer of duplicated node to its adjacent one in map.

**Make arbitrary pointer in list to point to next highest node**

Copy the next pointer to arbitrary pointer and run mergesort based on arbitrary pointer.

**To sort a linked list that is sorted alternating ascending and descending orders**

1. Separate two lists.

2. Reverse the one with descending order

3. Merge both lists.

**Rearrange linked list with nth coming after 1st, n-1th coming after 2 and so on:**

Divide the linked list in 2. Reverse the 2nd list and merge into 1st.

**Sort linked list which is already sorted on absolute values**

Given a linked list which is sorted based on absolute values. Sort the list based on actual values.

Input : 1 -> -2 -> -3 -> 4 -> -5

output: -5 -> -3 -> -2 -> 1 -> 4

Traverse through the list while a -ve node is encountered move it to front of list.

**To convert linked list in zigzag order wherein a>b<c>d<e>f..**

Input: 1->2->3->4

Output: 1->3->2->4

Approach 1: Do merge sort and swap alternate nodes.

Approach 2: Traverse through the list and maintain the order while checking either of ‘>’ or ‘<’ using a switch.

**To find decimal from linked list of binary:**

while (head != NULL)

{

// Multiply result by 2 and add

// head's data

res = (res << 1) + head->data;

// Move next

head = head->next;

}

Input : 1->0->0

Output : 4

**Find pair of a given sum in singly linked list:**

Approach 1 : For doubly linked list, it is easy as we maintain 2 pointers one from beginning and another from last while moving them forward and backward depending upon whether the current calculated sum is less or more than the requisite one. For singly linked list, we have to convert the list into XOR linked list so that we can traverse in backward direction too. After that, we can employ the same strategy as we used in case of doubly linked list.

Approach 2 : We can use recursion.

bool printPairs(Node<int>\*\* h1,Node<int>\* h2,int sum){

if(h2!=NULL){

bool ck = printPairs(h1,h2->getNext(),sum);

if(!ck || \*h1==h2)

return false;

while((\*h1)->getData()+h2->getData() <= sum ){

if((\*h1)->getData()+h2->getData()==sum)

cout<<"("<< (\*h1)->getData() <<", "<<h2->getData()<<")"<<" ";

\*h1 = (\*h1)->getNext();

if(\*h1==h2)

return false;

}

}

return true;

}

Subtract two numbers represented by linked list:

* Find the smaller list.
* Pad it with 0’s amounting to diff(size\_large\_list-size\_small\_list)
* Use recursion while keeping the borrow field as flag

**To flatten a linked list depth wise use stack.**

Merge K sorted linked lists

**Find longest length palindrome in linked list:**

While using iteratively reversing linked list check for prev->next---- > and compare with next->next----- > and count max length

**Trees**

Full Binary Tree: A tree with either 0 or 2 children is called a full binary tree.

In FBT, number of leaf nodes = number of internal nodes + 1

Complete binary tree: All levels full except the last one

Perfect Binary tree: In PBT, all levels are full and each internal node has 2 children

Degenerate/Pathological Tree: A tree in which each internal node has 1 child. It generally behaves as a linked list.

Balanced binary tree: In BBT, maximum difference between the levels of nodes in left and right

**Threaded Binary Tree:**

Inorder traversal of a Binary tree is either be done using recursion or with the use of a auxiliary stack. The idea of threaded binary trees is to make inorder traversal faster and do it without stack and without recursion. A binary tree is made threaded by making all right child pointers that would normally be NULL point to the inorder successor of the node (if it exists). Since the internal node needs to point to right child we can choose the leftmost child of its right subtree which will be its inorder successor.

[Sample tree:](#Sample_Tree)

10

/ \

6 12

/ \ / \

2 9 11 18

\ / \

6 16 20

**To delete a path < sum**

We have to delete the nodes in bottom-up manner and pass on the sum to the next iteration.

deleteSum(root, int sum) {

if(root->left == NULL && root->right == NULL) {

if(sum+root->data < k) {

delete root;

return true;

}

else

return false;

}

if(deleteSum(root->left, root->data+sum) && deleteSum(root->left, root->data+sum)) {

delete root;

return true;

}

return false;

}

Approach 2: Keep decrementing sum by the value == node data. when we reach at the end and sum is still greater than the leaf node, then delete it.

    if (root == NULL) return NULL;

    // Recur for left and right subtrees

    root->left = prune(root->left, sum - root->data);

    root->right = prune(root->right, sum - root->data);

    // If we reach leaf whose data is smaller than sum,

    // we delete the leaf.  An important thing to note

    // is a non-leaf node can become leaf when its

    // chilren are deleted.

    if (root->left==NULL && root->right==NULL)

    {

        if (root->data < sum)

        {

            free(root);

            return NULL;

        }

   }

    return root;

To find deepest left leaf node in a tree:

Do simple inorder traversal passing lvl+1 a

**Lowest Common Ancestor**

It finds the root which is deepest ancestor of 2 nodes. If both nodes < root, search for ancestor in left, else if > node, search in right.

    // If both n1 and n2 are smaller than root, then LCA lies in left

    if (root->data > n1 && root->data > n2)

        return lca(root->left, n1, n2);

    // If both n1 and n2 are greater than root, then LCA lies in right

    if (root->data < n1 && root->data < n2)

        return lca(root->right, n1, n2);

    return root;

**Approach 2** (If parent pointers are given) : Take first node and store all its ancestors in hashtable. Similarly do for second node. Now take second node ancestors 1-by-1 and check if it is present in parent’s map of first node.

**To print nodes which are at k distance from leaf**

int printKDistantfromLeaf(Node\* node, int k)

{

if(node==NULL)

return -1;

int x=1+printKDistantfromLeaf(node->left,k);

int y=1+printKDistantfromLeaf(node->right,k);

if(x==k || y==k)

printf("%d ",node->key);

}

**To print vertical order traversal**

**Approach 1**: Take a map of number and linked list. Do -1 for left subtree and +1 for right subtree and add (number, node) pair in map. At last, print the map

**Approach 2:**

Find min and max breadth distance from root. Then print

    // If this node is on the given line number

    if (hd == line\_no)

        cout << node->data << " ";

    // Recur for left and right subtrees

    printVerticalLine(node->left, line\_no, hd-1);

    printVerticalLine(node->right, line\_no, hd+1);

called by

for (int line\_no = min; line\_no <= max; line\_no++)

    {

        printVerticalLine(root, line\_no, 0);

}

**Approach 3**(Space Optimized) : Use DLL with each node pertaining to each vertical level.

       llnode.data = llnode.data + tnode.data;

        // Recursively process left subtree

        if (tnode.left != null)

        {

            if (llnode.prev == null)

            {

                llnode.prev = new LLNode(0);

                llnode.prev.next = llnode;

            }

            verticalSumDLLUtil(tnode.left, llnode.prev);

        }

        // Process right subtree

        if (tnode.right != null)

        {

            if (llnode.next == null)

            {

                llnode.next = new LLNode(0);

                llnode.next.prev = llnode;

            }

            verticalSumDLLUtil(tnode.right, llnode.next);

        }

**To print right view of binary tree**

Approach 1: Use level order traversal and print last node

Approach 2: Use recursion, as below. **Note that we are doing level order traversal in reverse order**

    // If this is the last Node of its level

    if (\*max\_level < level)

    {

        printf("%d\t", root->data);

        \*max\_level = level;

    }

    // Recur for right subtree first, then left subtree

    rightViewUtil(root->right, level+1, max\_level);

    rightViewUtil(root->left, level+1, max\_level);

**To print top view of binary tree:**

Do vertical traversal of tree and print the first node of vertical level.

**Max path sum in binary tree**

It is the path which carries the maximum exists in a complete path in a binary tree.

int maxPathSumUtil(struct Node \*root, int &res)

{

    // Base cases

    if (root==NULL) return 0;

    if (!root->left && !root->right) return root->data;

    // Find maximum sum in left and right subtree. Also

    // find maximum root to leaf sums in left and right

    // subtrees and store them in ls and rs

    int ls = maxPathSumUtil(root->left, res);

    int rs = maxPathSumUtil(root->right, res);

    // If both left and right children exist

    if (root->left && root->right)

    {

        // Update result if needed

        res = max(res, ls + rs + root->data);

        // Return maxium possible value for root being

        // on one side

        return max(ls, rs) + root->data;

    }

    // If any of the two children is empty, return

    // root sum for root being on one side

    return (!root->left)? rs + root->data:

                          ls + root->data;

**Check if a subtree exists in a tree**

An inorder and preorder/postorder uniquely identify a binary tree. Hence to check if S is a subtree of a tree T, store inorder and preorder of T in 2 arrays. Do same for S. Search inorder and preorder array of S In corresponding string array of T. If both searches are successful, then return true, else return false

**Convert BT to DLL**

Fix left and right pointers using inorder traversal.

void BinaryTree2DoubleLinkedList(node \*root, node \*\*head)

{

    // Base case

    if (root == NULL) return;

    // Initialize previously visited node as NULL. This is

    // static so that the same value is accessible in all recursive

    // calls

    static node\* prev = NULL;

    // Recursively convert left subtree

    BinaryTree2DoubleLinkedList(root->left, head);

    // Now convert this node

    if (prev == NULL)

        \*head = root;

    else

    {

        root->left = prev;

        prev->right = root;

    }

    prev = root;

    // Finally convert right subtree

    BinaryTree2DoubleLinkedList(root->right, head);

}

**To find the depth of node at odd level:**

// A recursive function to find depth of the deepest odd level leaf

int depthOfOddLeafUtil(Node \*root,int level)

{

    // Base Case

    if (root == NULL)

        return 0;

    // If this node is a leaf and its level is odd, return its level

    if (root->left==NULL && root->right==NULL && level&1)

        return level;

    // If not leaf, return the maximum value from left and right subtrees

    return max(depthOfOddLeafUtil(root->left, level+1),

               depthOfOddLeafUtil(root->right, level+1));

}

**To check if leaves are at same level**

Pass level+1 to next recursive call. Take a reference and set it to 0 initially. After that set it equal to level when a leaf node is encountered. After that compare level of each child with that leafLevel. If not equal, then return false, else return true.

**To print left view of binary tree**

Approach 1: Use level order and print first element.

Approach 2: Use inorder traversal, keeping track of level, Whenever you find a level max than the present max, print it because that will be the first:

    // If this is the first node of its level

    if (\*max\_level < level)

    {

        printf("%d\t", root->data);

        \*max\_level = level;

    }

    // Recur for left and right subtrees

    leftViewUtil(root->left, level+1, max\_level);

    leftViewUtil(root->right, level+1, max\_level);

**Diagonal Traversal/Sum of binary tree:**

Approach 1: using queue

while(!q.empty())

{

local = q.size();

sum = 0;

++level;

for(int i=0; i < local ; i++)

{

dummy = q.front();

ponder = dummy;

q.pop();

sum += dummy->element;

if(dummy->left != NULL) {

q.push(dummy->left);

ponder = dummy->left->right;

while(ponder) {

q.push(ponder);

ponder = ponder->right;

}

}

}

cout<<"Sum at level "<<level<<"# "<<sum<<endl;

}

**Approach 2**:

Use recursion similar to level order traversal, the only difference is that, we will increase the level while going left but keep it same while going right, as:

    // Store all nodes of same line together as a vector

    diagonalPrint[d].push\_back(root->data);

    // Increase the vertical distance if left child

    diagonalPrintUtil(root->left, d + 1, diagonalPrint);

    // Vertical distance remains same for right child

    diagonalPrintUtil(root->right, d, diagonalPrint);

**Bottom view of tree:**

Use level order traversal, passing -1 when we go left and +1 when we go right. Add elements to map as (sum, element\_in\_queue). traverse through the map and print last element in the queue of each map entry

**Perfect Binary Tree Specific Level Order Traversal**

For [this](#Sample_Tree) tree:

The traversal will be:

10 6 12 2 18 9 11 6 16

Do level order traversal and instead of popping one node, process 2 nodes at a time.

    while (!q.empty())

    {

       // Pop two items from queue

       first = q.front();

       q.pop();

       second = q.front();

       q.pop();

       // Print children of first and second in reverse order

       cout << " " << first->left->data << " " << second->right->data;

       cout << " " << first->right->data << " " << second->left->data;

       // If first and second have grandchildren, enqueue them

       // in reverse order

       if (first->left->left != NULL)

       {

           q.push(first->left);

           q.push(second->right);

           q.push(first->right);

           q.push(second->left);

       }

    }

**find distance of the closest leaf from ‘k’.**

Do breadth first search and find map entry of ‘k’ its nearest will be -1 and +1 of that index.

**To check if binary tree is complete or not**

A tree is complete if all nodes have either 0 or 2 children except the last level.

**Approach 1**: Do level order traversal, each level should have 2^level nodes. At last level half of the nodes popped from queue should have child while other shouldn’t

**Approach 2**: Count the number of nodes and use the following code:

    // If index assigned to current node is more than

    // number of nodes in tree, then tree is not complete

    if (index >= number\_nodes)

        return (false);

    // Recur for left and right subtrees

    return (isComplete(root->left, 2\*index + 1, number\_nodes) &&

            isComplete(root->right, 2\*index + 2, number\_nodes));

**To create a binary tree from an array whose each entry represents its parent node**

std::vector<node> bt; // constructed binary tree

void BuildBinaryTree(const std::vector<int>& parent)  
{  
 bt.resize(parent.size());

for (int i = 0; i < parent.size(); ++i)  
 {  
 if (parent[i] == -1)  
 root = &bt[i];  
 else if (bt[parent[i]].left == nullptr)  
 bt[parent[i]].left = &bt[i];  
 else  
 bt[parent[i]].right = &bt[i];

bt[i].val = i;  
 }  
}

**To check if a tree is a mirror/symmetric tree**

**if** (root1 && root2 && root1->key == root2->key)

**return** isMirror(root1->left, root2->right) &&

               isMirror(root1->right, root2->left);

**To find minimum depth of tree**

**Do level order traversal and break from queue loop when the first leaf node is encountered.**

**Binary Trees**

**Insertion**

/\* If the tree is empty, return a new node \*/

**if** (node == NULL) **return** newNode(key);

    /\* Otherwise, recur down the tree \*/

**if** (key < node->key)

        node->left  = insert(node->left, key);

**else** **if** (key > node->key)

        node->right = insert(node->right, key);

    /\* return the (unchanged) node pointer \*/

**return** node;

**To delete a node (3 cases)**

**When the node is leaf node** - Simply delete the node

**When the node has one child** – Replace the node with its child and delete the child.

**When the node has both left and right child** : Find the inorder successor of the node, replace the node to be deleted with that node and delete that inorder successor.

**if** (root == NULL) **return** root;

    // If the key to be deleted is smaller than the root's key,

    // then it lies in left subtree

**if** (key < root->key)

        root->left = deleteNode(root->left, key);

    // If the key to be deleted is greater than the root's key,

    // then it lies in right subtree

**else** **if** (key > root->key)

        root->right = deleteNode(root->right, key);

    // if key is same as root's key, then This is the node

    // to be deleted

**else**

    {

        // node with only one child or no child

**if** (root->left == NULL)

        {

**struct** node \*temp = root->right;

**free**(root);

**return** temp;

        }

**else** **if** (root->right == NULL)

        {

**struct** node \*temp = root->left;

**free**(root);

**return** temp;

        }

        // node with two children: Get the inorder successor (smallest

        // in the right subtree)

**struct** node\* temp = minValueNode(root->right);

        // Copy the inorder successor's content to this node

        root->key = temp->key;

        // Delete the inorder successor

        root->right = deleteNode(root->right, temp->key);

**To Handle Duplicates in Binary Tree:**

Add one for field to the node struct wherein we will store the count (the number of times the node appears in tree). To delete we find it and decrement the count. To Add we check if node is there then increment the count else add afresh.

**To Find closest leaf node to the given node:**

Take current node as root and find the closest leaf node and store its distance. Then start from the root. If that given node is in left subtree of main root then find closest leaf node in right subtree else vice versa and then compare it with the distance obtained above

**Inorder Non-threaded Binary Tree Traversal without Recursion or Stack**

To do this do inorder traversal using loop. You should have one flag too that will tell whether to go left or right. Initially it will be false, so go to left and traverse it and set flag to true. Now come back to parent. since that flag is true, go to right and set flag to false.

**To check if sum of uncovered nodes is same as that of covered nodes**

Find the sum of uncovered nodes by going towards left->left until the only right is available, that will give the sum of left boundary. Do the similar for right boundary. Now do inorder traversal and find the total sum, if it is == 2\*sum\_of\_uncovered\_nodes, the sums are equal.

**To Construct a binary tree from postorder traversal:**

FIn the postorder traversal, the rightmost number is the root. make that as root now find the transition part, one part of which is smaller than root and the other half is larger than root. Do the same for those 2 parts.

**To print root to leaf paths without recursion**

sUse stack and map. stack for traversing tree and map for storing <node, parent\_of\_this\_node> pair which can be used for printing using another stack. using the following:

while (curr)

    {

        stk.push(curr);

        curr = parent[curr];

    }

**To check if there is a edge whose removal will divide tree in 2 equal parts**

    // Compute sizes of left and right children

    int c = checkRec(root->left, n, res) + 1 +

            checkRec(root->right, n, res);

    // If required property is true for current node

    // set "res" as true

    if (c == n-c)

        res = true;

    // Return size

    return c;

Notes:

* Use ‘||’ operator below ‘left’ and ‘right’ calls if result can be fulfilled from either of the 2 routes.
* For a binary complete tree, its index is less than number of nodes at any time.
* Number of binary trees with n nodes are T(n) = (2n)! / (n+1)!n!

**STRINGS**

**Find duplicates in a string**

**Check if 1 string is rotation of another**

**Remove all chars from str1 which are in str2**

Create an array of char as char a[256], set a[<c>] for all observed in string1 and process the same.

**1Find the minimum windows in string which matches a given string**

C Maintain 2 hashmaps, one for main string and another for pattern. Also, take a variable count = 0 which will maintain the number of matches. Then traverse over the pattern and increment and fill its respective histogram. After that traverse over the main string filling its histogram and incrementing the count at character char when

String[char\_count] < pattern[char\_count]

When count reaches the pattern.length(), then start traversing the string from left with condition

while (!String.containsKey(char) || String.get(sc) > pattern.get(sc))

**Permutations of a string**

void permute(char \*a, int l, int r)

{

int i;

if (l == r)

printf("%s\n", a);

else

{

for (i = l; i <= r; i++)

{

swap((a+l), (a+i));

permute(a, l+1, r);

swap((a+l), (a+i)); //backtrack

}

}

}

**Lexicographic rank of String**

Use permutation, find count of all by considering the starting point as chars < first char. Then fix the first char and repeat the process.

e.g for STRING, it will be 4\*5! + 4\*4! + 3\*3! + 1\*2! + 1\*1! + 0\*0! = 597

597 + 1 = 598