**Data Structures**

[Linked List](#Linked_List)

[Trees](#Trees)

[Heaps](#Heap)

[Strings](#Strings)

[Hashmap](#HashMap)

[Arrays](#Arrays)

[Graphs](#Graphs)

Algorithms

Dynamic Programming

**Linked List**

> To find the middle node of a linked list, use 2 pointers, 1 slow one and another faster one. Slow pointer make a single jump at a time while faster pointer two. Start both the pointers in a loop and when faster one reaches the end, return the slower pointer.

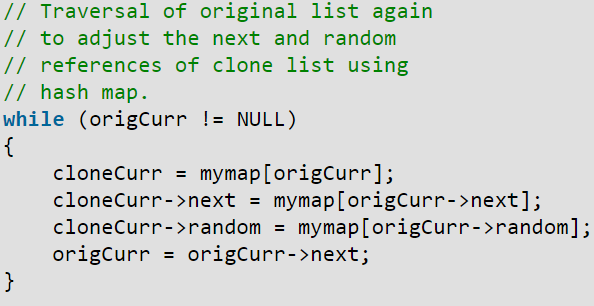
> The complete linked list deletion can be done using 2 pointers – cur and next

> Reversal of list iteratively just required use of 1 pointer – (LinkedList\*\* head\_ref), deduce cur and next from this.

> To check if linked list is palindrome or not, pass head as single and double pointer. Use double pointer to move right after end of each recursive call and compare data of current node in recursive call and node of double pointer.

> To create a copy of list and correct its arbitrary pointers, there are 3 methods –

>> hashing: In this first create the duplicate list and store the corresponding nodes of original and duplicate list in map. You can create a duplicate node and put it alongside the original node in a map



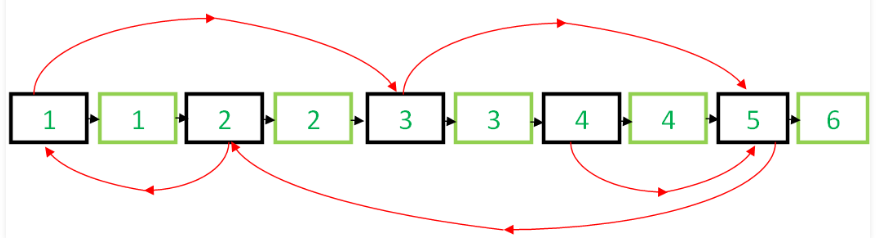
>> Insert ‘copy\_n’ nodes in between ‘original\_n’ and ‘original\_n+1’ node;

original->next->arbitrary = original->arbitrary->next; /\*TRAVERSE TWO NODES\*/

Restore back the nodes:

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

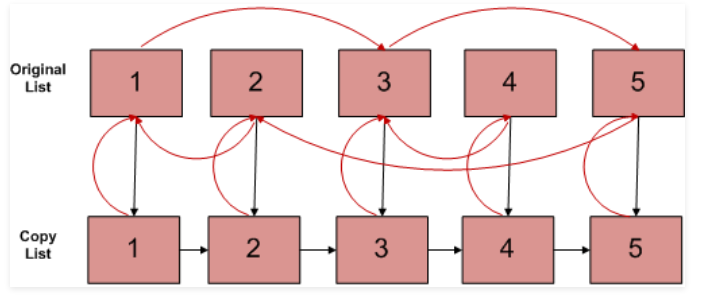
copy->next = copy->next->next;



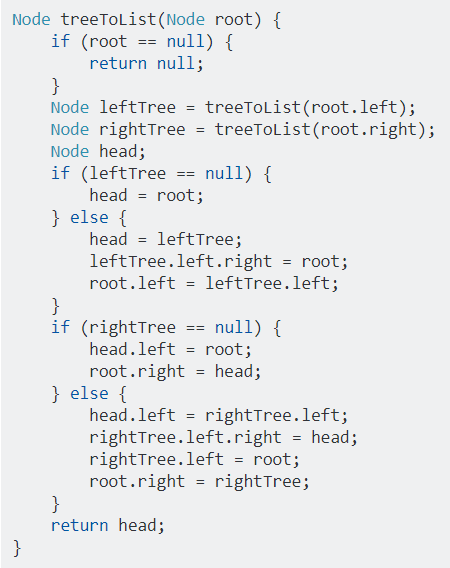
>> Last method is to take backup of next pointers of original list and then points its next to corresponding nodes in duplicate list, pointing arbit pointers of duplicate list pointing to corresponding nodes in original list and then set the arbit pointers of duplicate list as:

copy\_list\_node->arbit = copy\_list\_node->arbit->arbit->next;

copy\_list\_node = copy\_list\_node->next;



> To convert a BT to Circular DLL, first start with simple tree with 3 nodes – 1 root and 2 nodes signifying left and eight nodes and then generalizes it for whole tree.



> Intersection point of 2 lists. There are 3 methods:

>> Count number of nodes in 1st and 2nd list. Traverse 1st list for abs(1st\_list\_len – 2nd\_list\_len) and now start comparing pointers. If any of those matches, that’s the intersection point

>> Traverse 1st list and put all addresses in a hashmap. Now, traverse the 2nd list and check if any of the node is in hashmap. If found, you’ve got the intersection point, else both lists don’t intersect.

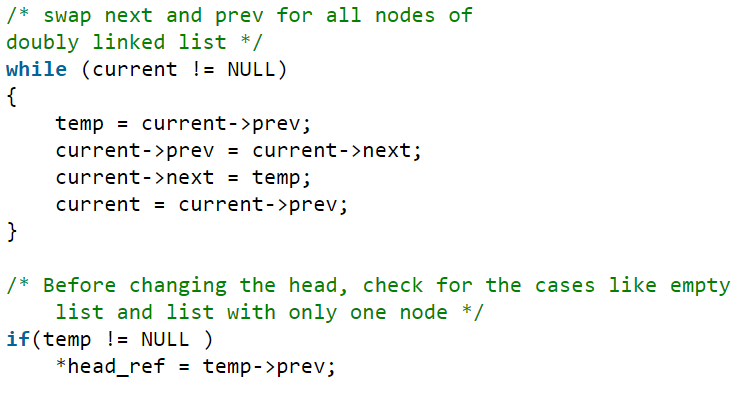
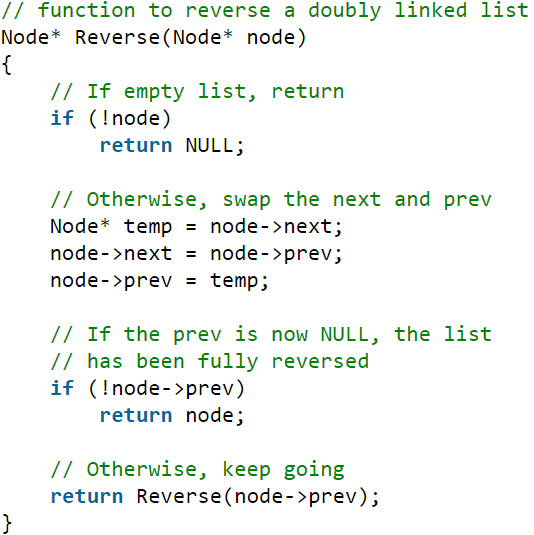
>> Create loop in 1st list and check for loop in 2nd list. It’s just like finding the loop in a list

> To remove duplicates in unsorted linked list

>> Use merge sort and remove duplicates

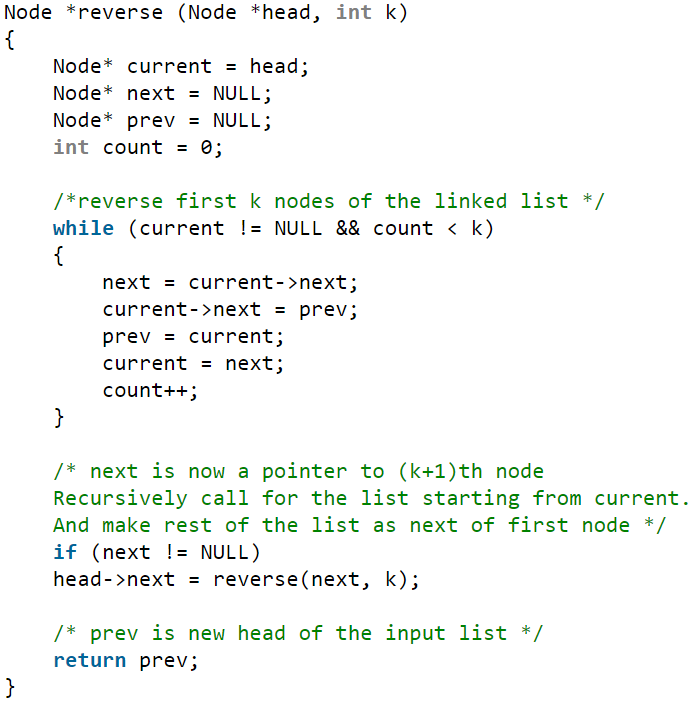
>> Use hashmap. While traversal, if node’s data is in hash, delete that node else add data of that node to hash map.

> Reversal of DLL. Two methods- Iterative and Recursive. In recursive method we first swap ‘next’ and ‘prev’ pointers of node and pass node->prev to next recursive call, while in iterative method, we use pointers

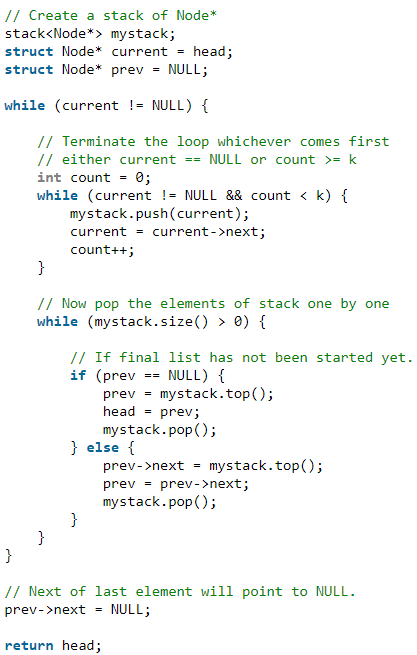


> Reverse every ‘k’ nodes in a linked list:

Use iteration to reverse the linked list and recursion to complete the flow.



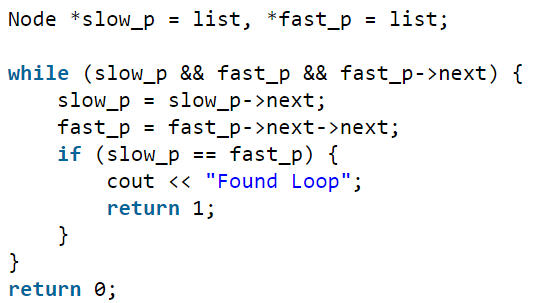
We can use a stack too



> For alternate reverse, move forward for ‘k’ elements before making the recursive call.

> Detect loop in linked list:

There are two methods – use a hashmap or use floyd’s cycle detection algorithm



**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;**

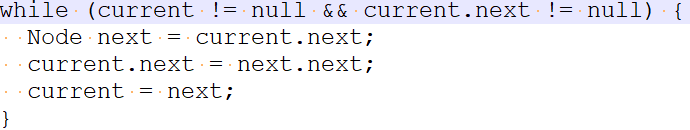
**}**

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

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

**}**

> Alternate split – Split the linked list in 2



> MergeSort on LinkedList

Pseudocode:

recur(&l) {

Split the linked list in 2 using hare and tortoise algorithm. Name those 2 parts, say ‘a’ and ‘b’

recur(&a)

recur(&b)

SortedMerge(&a, &b)

}

> Flatten a linked list with right and down pointers

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

Leaf Case: When the two pointer points to last sublist.

// The main function that flattens a given linked list

Node\* flatten (Node\* root)

{

// Base cases

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

return root;

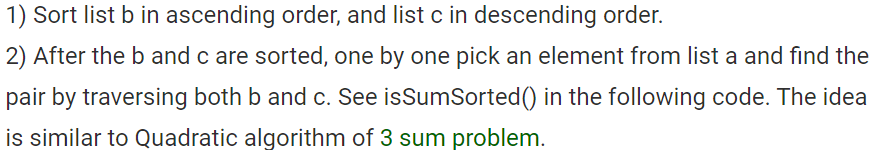
// Merge this list with the list on right side

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

}

Another method could be to append all down list to the end and then call merge sort on that list.

> Find triplet in 3 linked list so that a node from 1 list (a) is sum of 2 nodes from other 2 lists (b & c):



**Why we need to move fast pointer by factor of 2:**  
Let us suppose the length of the list which does not contain the loop be s, length of the loop be t and the ratio of fast\_pointer\_speed to slow\_pointer\_speed be k.

Let the two pointers meet at a distance j from the start of the loop.

So, the distance slow pointer travels = s + j. Distance the fast pointer travels = s + j + m \* t(where m is the number of times the fast pointer has completed the loop). But, the fast pointer would also have traveled a distance k \* (s + j) (k times the distance of the slow pointer).

Therefore, we get k \* (s + j) = s + j + m \* t.

s + j = (m / k-1)t.

Hence, from the above equation, length the slow pointer travels is an integer multiple of the loop length.

For greatest efficiency , (m / k-1) = 1 (the slow pointer shouldn't have traveled the loop more than once.)

therefore , m = k - 1 => k = m + 1

Since m is the no.of times the fast pointer has completed the loop , m >= 1 . For greatest efficiency , m = 1.

therefore k = 2.

-if we take a value of k > 2 , more the distance the two pointers would have to travel.

> 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;

  }

> To Extract Leaves of a Binary Tree in a Doubly Linked List

Have a recursive function returning node pointer. Go for reverse in-order traversal. Perform DLL operation in case left and right of node is NULL and return NULL for them as in:

Node\* extractLeafList(Node \*root, Node \*\*head\_ref)

{

if (root == NULL) return NULL;

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

root->right = \*head\_ref;

// Change left pointer of previous head

if (\*head\_ref != NULL) (\*head\_ref)->left = root;

// Change head of linked list

\*head\_ref = root;

return NULL; // Return new root

}

// Recur for right and left subtrees

root->right = extractLeafList(root->right, head\_ref);

root->left = extractLeafList(root->left, head\_ref);

return root;

}

> hh

**Given K sorted linked lists merge them in place with total elements as N**

**Approach 1** : Naïve method

Pick first 2 lists merge them. Pick the merge list and merge it with 3rd sorted list and so on.

T(N) = O (N^2)

**Approach 2** : Using heap.

At every instant, you need the minimum of the head of all the k linked list. Once you know the minimum, you can push the node to your answer list, and move over to the next node in that linked list.

T(N) = O (N log N), S(N) = O(K)

**Approach 3** : Using map

Iterate over all lists and store their data in map with count. If count > 1, add to new list and –count.

T(N) = Insertion – O(NlogN) + Retrieval = O(NlogN) = O(NlogN) S(N) = O(N)

**Approach 4** : Divide and conquer.

Solve the problem for first k/2 and last k/2 list. Then you have 2 sorted lists. Then simply merge the lists.

Analyze the time complexity.

T(N) = 2 T(N/2) + N

T(N) = O (N log N) S(N) = No additional space required

**Divide and Conquer Solution:**

// The main function that takes an array of lists

// arr[0..last] and generates the sorted output

Node\* mergeKLists(Node\* arr[], int last)

{

    // repeat until only one list is left

    while (last != 0)

    {

        int i = 0, j = last;

        // (i, j) forms a pair

        while (i < j)

        {

            // merge List i with List j and store

            // merged list in List i.SortedMerge Method is defined above

            arr[i] = SortedMerge(arr[i], arr[j]);

            // consider next pair

            i++, j--;

            // If all pairs are merged, update last

            if (i >= j)

                last = j;

        }

    }

    return arr[0];

}

**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:**

**In this method tree is created from leaf to root**

BinaryTree\* sortedListToBST(ListNode \*& list, int start, int end) {

if (start > end) return NULL;

// same as (start+end)/2, avoids overflow

int mid = start + (end - start) / 2;

BinaryTree \*leftChild = sortedListToBST(list, start, mid-1);

BinaryTree \*parent = new BinaryTree(list->data);

parent->left = leftChild;

list = list->next;

parent->right = sortedListToBST(list, mid+1, end);

return parent;

}

BinaryTree\* sortedListToBST(ListNode \*head, int n) {

return sortedListToBST(head, 0, n-1);

}

**Flatten a multilevel linked list**

The idea of solution is, we start from first level, process all nodes one by one, if a node has a child, then we append the child at the end of list, otherwise we don’t do anything. After the first level is processed, all next level nodes will be appended after first level. Same process is followed for the appended nodes.

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 merge sort 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 sorted 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**

Use heap:

Approach: Pick first element from each list and insert it into heap. Now, pop the root element and push the next node of the list to which popped node belonged to.

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

Loop over the linked list and one-by-one keep reversing the linked list and after each reverse compare the reversed list with the remaining list. Whole list will be reversed at last, so reverse it again to get the original.

**To check if linked list is palindrome**

Use a function same as printing the reverse of list. When you reach the end, start the static pointer first = first->next and at each step compare the data at left node with the data at end node.

**Notes**:  
> Two ways of updating in loop: If we want no extra argument in function think returning pointers/variables from the recursive calls otherwise you have to maintain an additional argument which you need to update e.g. – head pointer reference is passed, if needed to be updated or we can sent back new node and assign that to node to append to as \*->next = recurCall (node\*) rather than – recurCall (node\*, head)

> If it seems that you need 2 recursive calls, try 1 loop and recursive calls inside it

>

**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:**

In-order 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 in-order 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 in-order 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 in-order 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.

bool 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->right, 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 in-order traversal passing lvl+1 and m.

**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 hash-table. 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 root**

**(To print from leaf, use array to store complete path, didn’t find any other solution)**

int printKDistantfromLeaf(Node\* node, int k)

if( k == 0 )

{

printf( "%d ", root->data );

return ;

}

else

{

printKDistant( root->left, k-1 ) ;

printKDistant( root->right, k-1 ) ;

}

**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 (level > \*max\_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

// Below condition also takes into account if the max path sum

// doesn’t pass through root node.

        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)

root = \*head;

    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:**

**Approach 1** : 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

**Approach 2**: Use Vertical order, print last node of each traversal.

**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’ it’s nearest will be -1 and +1 of that index.

Another Solution: Find all ancestors of given node and for each ancestor find closest leaf and also leaf from that root.

**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 using queue, while pushing left/right set flag to true in case of empty child. When we go for other child right/left and it is present while flag was true return false.

Otherwise enqueuer.

**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 who’s 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 in-order successor of the node, replace the node to be deleted with that node and delete that in-order 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.

**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:**

Find 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**

Use stack and. Go left->left pushing all entries in stack until NULL is encountered. When null is encountered print path and pop back node from stack, push its right, if !NULL and go left->left pushing again on stack for traversing tree. Stop when stack is empty

**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;

**Clone a binary tree with random pointers:**

The solution is similar to the linked list in which we store the mapping of original node to clone node. After we have created a tree with the standard method of inorder traversal. We can use map to modify random pointers of clone nodes

**Create a tree from inorder and postorder traversal**

The end node of postorder traversal is the root. Hence, make that as root and search for the index in inorder. Recursively pass the start and end index of inorder traversal to the recursion tree and keep picking the last node as root

/\* Pick current node from Postorder traversal using

postIndex and decrement postIndex \*/

Node \*node = newNode(post[\*pIndex]);

(\*pIndex)--;

/\* If this node has no children then return \*/

if (inStrt == inEnd)

return node;

/\* Else find the index of this node in Inorder

traversal \*/

int iIndex = search(in, inStrt, inEnd, node->data);

/\* Using index in Inorder traversal, construct left and

right subtress \*/

node->left = buildUtil(in, post, inStrt, iIndex-1, pIndex);

node->right= buildUtil(in, post, iIndex+1, inEnd, pIndex);

**To print cousins of a node**

**Approach 1**: Use recursion, pass level-1 to each call. When level = 2, it means we are 1 level above. So check if the searched node is either left or its right. If it is, return else print its left and right children

**Approach 2**: Use queue for level order traversal. While traversing before pushing left and right check if any of left or right of given node is that node do not push in queue.

**To find diameter if binary tree**

/\* Function to find height of a tree \*/

int height(Node\* root, int& ans)

{

if (root == NULL)

return 0;

int left\_height = height(root->left, ans);

int right\_height = height(root->right, ans);

// update the answer, because diameter of a

// tree is nothing but maximum value of

// (left\_height + right\_height + 1) for each node

ans = max(ans, 1 + left\_height + right\_height);

return 1 + max(left\_height, right\_height);

}

**To print Maximum Consecutive Increasing Path Length**

At each node we need information of its parent node, if current node has value one more than its parent node then it makes a consecutive path, at each node we will compare node’s value with its parent value and update the longest consecutive path accordingly.

For getting the value of parent node, we will pass the (node\_value + 1) as an argument to the recursive method and compare the node value with this argument value, if satisfies, update the current length of consecutive path otherwise reinitialize current path length by 1

// if root data has one more than its parent

    // then increase current length

    if (root->data == expected)

        curLength++;

    else

        curLength = 1;

    //  update the maximum by current length

    res = max(res, curLength);

    // recursively call left and right subtree with

    // expected value 1 more than root data

    longestConsecutiveUtil(root->left, curLength,

                           root->data + 1, res);

    longestConsecutiveUtil(root->right, curLength,

                           root->data + 1, res);

**Find if there is a pair in root to a leaf path with sum equals to root’s data**

**Approach 1 :** Do preorder traversal. if node != NULL, check if root\_sum – node\_value is there in hashmap, if its there then return true else insert that node in map. At the end of recursion remove that node.

if(node == NULL)

return;

if(node!= NULL) {

// check in map for (root\_sum – node\_value) if found then ok else insert it in map

}

recur(left);

recur(right);

// remove node from map

**Find inorder successor:**

If node->right != NULL, then successor is the minimum in right subtree. Otherwise start from root and set root as successor when going left

**Find all k sum paths in a tree, wherein the starting node needn’t necessarily be the root node and last node the leaf node**

Do normal preorder traversal pushing each node in vector. After each recursion track back the vector, looping through size -1 -> 0 and print if sum of elements leads to k. At the end of recursion remove the node.

**Construct a BST from linked list**

Solution: In this, we’ll create the list bottom up. First we will create left node, then we’ll create root. Linking left to root and then attach right to root->right.

Following is the solution:

struct TNode\* sortedListToBSTRecur(struct LNode \*\*head\_ref, int n)

{

    /\* Base Case \*/

    if (n <= 0)

        return NULL;

    /\* Recursively construct the left subtree \*/

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

    /\* Allocate memory for root, and link the above constructed left

       subtree with root \*/

    struct TNode \*root = newNode((\*head\_ref)->data);

    root->left = 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) which is n-n/2-1\*/

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

    return root;

}

Check if a tree is height balanced

bool isBalanced(struct node \*root, int\* height)

{

/\* lh --> Height of left subtree

rh --> Height of right subtree \*/

int lh = 0, rh = 0;

/\* l will be true if left subtree is balanced

and r will be true if right subtree is balanced \*/

int l = 0, r = 0;

if(root == NULL)

{

\*height = 0;

return 1;

}

/\* Get the heights of left and right subtrees in lh and rh

And store the returned values in l and r \*/

l = isBalanced(root->left, &lh);

r = isBalanced(root->right,&rh);

/\* Height of current node is max of heights of left and

right subtrees plus 1\*/

\*height = (lh > rh? lh: rh) + 1;

/\* If difference between heights of left and right

subtrees is more than 2 then this node is not balanced

so return 0 \*/

if((lh - rh >= 2) || (rh - lh >= 2))

return 0;

/\* If this node is balanced and left and right subtrees

are balanced then return true \*/

else return l&&r;

}

In case, you want to send back huge data in recursion, rather than sending pointer or variable, try returning a structure.

**A Tree is BST if following is true for every node x.**

**The largest value in left subtree (of x) is smaller than value of x.**

**The smallest value in right subtree (of x) is greater than value of x.**

**To find largest BST in BT**

// Returns Information about subtree. The

// Information also includes size of largest

// subtree which is a BST.

Info largestBSTBT(Node\* root)

{

    // Base cases : When tree is empty or it has

    // one child.

    if (root == NULL)

        return {0, INT\_MIN, INT\_MAX, 0, true};

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

        return {1, root->data, root->data, 1, true};

    // Recur for left subtree and right subtrees

    Info l = largestBSTBT(root->left);

    Info r = largestBSTBT(root->right);

    // Create a return variable and initialize its

    // size.

    Info ret;

    ret.sz = (1 + l.sz + r.sz);

    // If whole tree rooted under current root is

    // BST.

    if (l.isBST && r.isBST && l.max < root->data &&

            r.min > root->data)

    {

        ret.min = min(l.min, min(r.min, root->data));

        ret.max = max(r.max, max(l.max, root->data));

        // Update answer for tree rooted under

        // current 'root'

        ret.ans = ret.sz;

        ret.isBST = true;

        return ret;

    }

    // If whole tree is not BST, return maximum

    // of left and right subtrees

    ret.ans = max(l.ans, r.ans);

    ret.isBST = false;

    return ret;

}

To check if each internal node of BST has exactly once child.

Solution: The next successor will be either smaller of larger and that too will be the same property of last node w.r.t the current node.

bool hasOnlyOneChild(int pre[], int size)

{

    int nextDiff, lastDiff;

    for (int i=0; i<size-1; i++)

    {

        nextDiff = pre[i] - pre[i+1];

        lastDiff = pre[i] - pre[size-1];

        if (nextDiff\*lastDiff < 0)

            return false;;

    }

    return true;

}

To correct 2 swapped nodes:

Solution: 2 situations: Either 2 nodes are adjacent or are far apart.

// Recur for the left subtree

correctBSTUtil( root->left, first, middle, last, prev );

// If this node is smaller than the previous node, it's violating

// the BST rule.

if (\*prev && root->data < (\*prev)->data)

{

// If this is first violation, mark these two nodes as

// 'first' and 'middle'

if ( !\*first )

{

\*first = \*prev;

\*middle = root;

}

// If this is second violation, mark this node as last

else

\*last = root;

}

// Mark this node as previous

prev = root;

// Recur for the right subtree

correctBSTUtil( root->right, first, middle, last, prev );

**Convert a BST to a Binary Tree such that sum of all greater keys is added to every key**

Do reverse in-order traversal and keeping summing up old nodes while adding to current node the sum.

**To find triplet in a tree whose sum is 0**

**2 approaches:**

**Approach 1**: Store the tree in array after inorder traversal. Find the triplet by fixing 1 element and doing l++/r—in array

**Approach 2**: Convert tree to DLL. Now, use the same method. But here, caveat is that you don’t need array and hence no extra space.

**Delete the value outside range**

// Removes all nodes having value outside the given range and returns the root

// of modified tree

node\* removeOutsideRange(node \*root, int min, int max)

{

   // Base Case

   if (root == NULL)

      return NULL;

   // First fix the left and right subtrees of root

   root->left =  removeOutsideRange(root->left, min, max);

   root->right =  removeOutsideRange(root->right, min, max);

   // Now fix the root.  There are 2 possible cases for toot

   // 1.a) Root's key is smaller than min value (root is not in range)

   if (root->key < min)

   {

       node \*rChild = root->right;

       delete root;

       return rChild;

   }

   // 1.b) Root's key is greater than max value (root is not in range)

   if (root->key > max)

   {

       node \*lChild = root->left;

       delete root;

       return lChild;

   }

   // 2. Root is in range

   return root;

}

**Segment Tree:**

Segment Trees is a Tree data structure for storing intervals, or segments, It allows querying which of the stored segments contain a given point. It is, in principle, a static structure; that is, its content cannot be modified once the structure is built. It only uses O(N lg(N)) storage.

The leaves in segment tree are elements of input array while the internal node represents a range of value. The problems like : finding the maximum in a given range, finding the minimum in a given range can be solved in O(logn) time using segment tree in which the internal node will store the result.



Segment trees are used to solve range minimum queries problem in O(logn) which otherwise would take O(n) time to compute.

**To find sum of nodes at k-th level represented in the form of string as** “"(0(5(6()())(4()(9()())))(7(1()())(3()())))"

Start from left, when ‘(‘ is encountered increment the level, when ‘)’ is encountered decrement the level. When level is same as needed add that to sum which is initially initialized to 0.

To convert Sorted DLL to Tree

Approach 1 O(nlogn) : Use array like approach, take the middle, make it root and recur for its left and right

Approach 2 O(n):

/\* The main function that constructs balanced BST and returns root of it.

head\_ref --> Pointer to pointer to head node of Doubly linked list

n --> No. of nodes in the Doubly Linked List \*/

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 store all root->leaf paths resulting in a given sum:**

void findListWithGivenSum(TreeNode \*ptr, int count, int sum, vector<int>& tmp\_vec)

{

if(ptr == NULL)

return;

//cout<<"Count is: "<<count<<endl;

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

if(count+ptr->val == sum) {

//cout<<"now pushing back\n";

tmp\_vec.push\_back(ptr->val);

result.push\_back(tmp\_vec); //vector< vector<int> > result; tmp\_vec.pop\_back();

return;

}

}

count += ptr->val;

//cout<<"After addition, count: "<<count<<endl;

tmp\_vec.push\_back(ptr->val);

findListWithGivenSum(ptr->left, count, sum, tmp\_vec);

findListWithGivenSum(ptr->right, count, sum, tmp\_vec);

count -= ptr->val;

tmp\_vec.pop\_back();

}

Notes:

> To handle the case in which we need to check if one child is present and other doesn’t, do it this way (2nd check will find that)

If(!tree->right && !tree->left)

// if both left and right child are absent

If(tree->left == NULL || tree->right == NULL)

// Now only one of them is present..

> Function to check 2 intervals:

bool doOVerlap(Interval i1, Interval i2)

{

    if (i1.low <= i2.high && i2.low <= i1.high)

        return true;

    return false;

}

**Red-Black Trees**

RB are the balanced binary trees which guarantees height of O(logn)

Invariants:

* Each node is either red or black.
* Root is black.
* No 2 reds in a row.
* Every root->NULL path has same number of black nodes.

A chain of 3 cannot be a red-black tree.

Every red-black tree has height of < 2\*log(n+1)

To make the tree balanced, we do left and right rotations.

**Insertion in RB-tree**

We insert in tree just like a normal BST. If an invariant is destroyed then do recoloring and/or rotations.

**Add new node as red** because making it black will destroy the equal-black-nodes in root->leaf path.

In recoloring, if 2 child are of red color while their parent is black. Recolor that parent to red and convert two red’s to black.

Do check: splay trees

**HEAP**

Heap is a data structure which is represented similar to a binary tree with each node having either 0, 1 or 2 children. We can have either min-heap or max-heap. In min-heap, we have minimum element at the top while in max-heap, we have maximum element at top. Mostly, Heap is implemented using Array as the data container.

Supported Operations:

* Extract Min or Max - O(logn)
* Insertion - O(logn)
* Delete - O(logn)
* Creation of Heap - O(nlogn)

**To Extract Min from min-heap**

> Move last leaf to new root

> Delete last leaf

> Heapify

**Median Maintenance:**

Use two heaps - low and high

Low heap will contain small half of integers while high heap will have large half integers. Median of the added integers will be either average of max of low heap and min of high heap in case number of elements are equal in both heaps or it will be max of low heap or min of high heap otherwise.

Maintain min-heap for upper half of numbers and max-heap for lower half of the numbers.

**Hash Table**

A kind of table that can be used data that employ association.

Some applications:

> De-duplication of data – Either read from file or from stream.

> 2-Sum problem – To find couple whose sum is equal to a given sum. For each x, look for sum – x in hash table.

> In symbol table.

> To block network traffic - By looking into a hash table of black list ip’s

> In general, Use hash table to avoid exploring any configuration more than once. One example is configuration of chess board.

Hash function takes as input key and spit out a position in the array.

or A|h(x)| where h(x) is a hash function.

**Collision**: When 2 entries map to the same value, collision results.

**Resolution**:

**Chaining**: We link colliding entries and put them in same bucket.

**Open Addressing**: No multiple entries. When we find a collision, probe the table for next free entry and insert the element in that.

**Double chaining**: Use both independently. If one hash function generates collision, use second hash function.

Open Hashing (Separate Chaining): In open hashing, keys are stored in linked lists attached to cells of a hash table.

Closed Hashing (Open Addressing): In closed hashing, all keys are stored in the hash table itself without the use of linked lists.

**Cuckoo Hashing**:

A hashing technique in which we maintain 2 tables instead of 1 so that when conflict arises then we look for empty location in table 2. If there is collision in both tables then one of the older key is kicked out and re-positioned, which in turns kicks-out other keys in recursion.

**2-Sum problem when we have to find sums which lie in a given range:**  
> Store the elements in a set.

> for each element, find lower and upper bound in both left and right.

> calculate upper-lower for both left and right and sum them henceforth.

**To find k-most frequent elements in input stream.**

1. Maintain a Linked List with decreasing order of frequency. Each node of linked list will have the number and its frequency.   
2. Maintain a hash map with key as number and value as the pointer to the node in the linked list.   
3. If a new number comes, add it to the tail of the linked list, maintaining the hash map.   
  
The cost of maintaining the list for every number is O(1).   
Reason:   
1. When the list is empty - add a node O(1)   
2. When node is not in list - add a node O(1)   
3. when frequency of a node changes, it moves before the previous node - O(1)   
  
The cost of returning the top occurred (k) numbers - O(k) - returning the first k numbers from the linked list.

**To find k-largest/minimum elements in a stream**

Maintain a min-heap/max-heap respectively

**To find palindrome in running stream**

Use rolling hash method of Robin-Karp algorithm: Store hash of 1st half and hash of 2nd half and compare after each insertion. If they match, match character-by-character of 2 substrings to check if the two halves are of an actual palindrome.

4-Sum in array

Problem: Find quadruplets in array – a, b, c, d such that sum of those four integers is equal to a given target

Solution:

> Sort the array.

> Use 2 loops. i=0 to size-3 and j = i+1 to size-2

> Fix initial 2 values as [i] and [j] and loop over remaining ones while increasing if result is getting smaller and decreasing the higher index in case result is larger than expected.

TreeMap:

TreeMap is basically mapped data inside a tree. C++ provided map<T t, U u> as class which can be used as TreeMap

**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.

**Find 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

main\_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.

Let the given string be “STRING”. In the input string, ‘S’ is the first character. There are total 6 characters and 4 of them are smaller than ‘S’. So there can be 4 \* 5! smaller strings where first character is smaller than ‘S’, like following

R X X X X X  
I X X X X X  
N X X X X X  
G X X X X X

Now let us Fix S’ and find the smaller strings staring with ‘S’.

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

**Longest Consecutive Subsequence**

To find longest consecutive subsequence wherein the elements in subsequence are dispersed.

**Approach 1 O(nlogn)**: Sort the array and find the same.

**Approach 2 O(n)**: Use hashing – Insert all elements in hash. Re-traverse the array and look for the element first in sequence then search for subsequent elements in hash.

**Approach 3**: Dynamic programming. Single table and O(n^2)

**Longest Common substring:**

Solution: Use dynamic programming using a 2-D array as int LCS[M][N]

Code below:

for (int i=0; i<=m; i++) {

for (int j=0; j<=n; j++) {

if (i == 0 || j == 0) {

LCSuff[i][j] = 0;

continue;

} else if (X[i-1] == Y[j-1]) {

LCSuff[i][j] = LCSuff[i-1][j-1] + 1;

result = max(result, LCSuff[i][j]);

} else {

LCSuff[i][j] = 0;

}

}

}

**To make the string palindromic:**

Solution: Check the number of characters which are repeated odd number of times. Then, requisite number will be the count-1 since one extra character is allowed flanked by palindromic sub-string

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

{

// if current element is the starting

// element of a sequence

if (S.find(arr[i]-1) == S.end())

{

// Then check for next elements in the

// sequence

int j = arr[i];

while (S.find(j) != S.end())

j++;

// update optimal length if this length

// is more

ans = max(ans, j - arr[i]);

}

}

**Check for Palindrome after every character replacement**

Traverse through the string and store unequal indices in set/map. For every query, if both incoming indices are not equal then simply update the string but if both incoming indices match then remove them from set and count the number of elements in set.

**Arrays**

**Longest Increasing Sub-sequence:**

Problem: Find the sub-sequence (not necessarily contiguous) which is increasing and contains maximum elements

Approach: Use DP, using 2 loops i=0->n; j=0->i we can compare each a[j] with a[i] and update the value in lis[i], another array used to store result.

**Find whether an array is subset of another array**

**Approach 1**: Sort both arrays and compare like merge sort.

**Approach 2**: Use hashing, Store array 1 in hash and compare array 2 members with hash elements.

**Find largest sub-array with maximum number of 0’s and 1’s**

Create another temp array which will store the difference of number of 1’s and 0’s at a given step. Now, scan from left to right and calculate and store the same. After complete pass, we just need to find the two elements in temp array which are far apart. Max range could be –n to n. so you can make a 2n+1 element table and store in it the indices of the first and last time each number appears. From there, it's easy to find the longest range. Overall, this needs O(n) space and everything can be populated and searched in O(n) time.

**Find if there is sub-array with 0 sum**

The approach will be the same as that of above. Create a hashtable and store in it the intermediate sum calculated at an index while we traverse the array from left to right. If a partial sum is already present in hashtable then answer is YES, else add that sum to hashtable.

**Find first repeating element**

Use hash/trie and DLL

**Find largest sub-array with contiguous elements**

**Approach 1 O(n^2)** - A sub-array has contiguous elements if and only if the difference between maximum and minimum elements in sub-array is equal to the difference between last and first indexes of sub-array. So the idea is to keep track of minimum and maximum element in every sub-array.

**Approach 2 O(nlogn)**: Sort the array and check the sequence.

**Approach 3 O(n) -** If all elements are distinct, then a subarray has contiguous elements if and only if the difference between maximum and minimum elements in subarray is equal to the difference between last and first indexes of subarray. So the idea is to keep track of minimum and maximum element in every subarray.

**Count distinct elements in every window of size k**

Use a hashmap, insert first k nodes in it. Find the distinct while inserting. After that slide the window 1-by-1 removing the left element and add/increment count right element. If the inserted element is new one, it is distinct.

**Find if an array can be divided in pairs whose sum is divisible by a given element k**

Traverse through array and store (remainder, frequency) in map. Now, traverse again and for each element. If its remainder is x such that 2\*x = k, then there should be even number of such elements. or if remainder is 0 then also even no. of elements, else number of occurrences of remainder must be equal to number of occurrences of k – remainder.

**Dutch national flag problem**

**We are given an array of integers of values 0, 1 and 2. The task is to arrange them in increasing order of 0, 1 and then 2. Complexity should be O(n)**

The program will use 3 elements i0, i and i2. i0 will point to the last 0 discovered. ‘i’ will be the main index used for traversal and left of which will contain 0’s and 1’s.’ i2’ will be set to extreme right initially and decremented as we find 2’s

while( i < i2 ) {

if(arr[i] == 0) {

swap(arr[i0+1], arr[i]);

i0++; i++;

}

else if(arr[i] == 2 ) {

swap(arr[i2-1], arr[i]); //Don't increment ‘i’ because we don't know what’s the current element after swap

--i2;

}

else

i++;

}

map<int, int> freq;

// Count occurrences of all remainders

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

freq[arr[i] % k]++;

// Traverse input array and use freq[] to decide

// if given array can be divided in pairs

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

{

// Remainder of current element

int rem = arr[i] % k;

// If remainder with current element divides

// k into two halves.

if (2\*rem == k)

{

// Then there must be even occurrences of

// such remainder

if (freq[rem] % 2 != 0)

return false;

}

// If remainder is 0, then there must be two

// elements with 0 remainder

else if (rem == 0)

{

if (freq[rem] & 1)

return false;

}

// Else number of occurrences of remainder

// must be equal to number of occurrences of

// k - remainder

else if (freq[rem] != freq[k - rem])

return false;

}

return true;

**Find the missing numbers in an unsorted array of size 'n' in which numbers are ranged from 1 to n**

To find the same use that same array.

Decrement count of each element by 1 and then for every encountered number add 'n' to that element's original position after modulus. Modulus is used so that we get correct number if that number has already gone > n (Number already encountered) . At last divide that position by n.

void printfrequency(int arr[],int n)

{

for(int j =0;j<n;j++)

{

arr[j] = arr[j]-1;

}

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

{

arr[arr[i]%n] = arr[arr[i]%n] + n;

}

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

{

cout << i + 1<<" -> "<<arr[i]/n<<endl;

}

}nd pairs with given sum such that elements of pair are in different rows

# Create a hash with value as key and its position as index. Start from left top and search for the element - ( sum – current\_value ) if element is there in the hash, compare rows of both, if equal then skip else continue;

# **To find the smallest range in k sorted list, with each of size n**

# Use heap of k elements, find the min and find the difference and now insert the element from the list whose minimum was extracted. Find the difference and continue.

**To find the maximum occurring element in array**

Iterate though input array arr[], for every element arr[i], increment arr[arr[i]%k] by k, where k is the number of elements in array

**Largest Sum Contiguous Subarray - Find the sum of contiguous subarray within an array of numbers which has the largest sum (Solved using Kadane’s Algorithm)**

int maxSubArraySum(int a[], int size)

{

int max\_so\_far = INT\_MIN, max\_ending\_here = 0;

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

{

max\_ending\_here = max\_ending\_here + a[i];

if (max\_so\_far < max\_ending\_here)

max\_so\_far = max\_ending\_here;

if (max\_ending\_here < 0)

max\_ending\_here = 0;

}

return max\_so\_far;

}

**Find the missing number in an array of dimension ‘n’ which contains the numbers from 0 to n**

Do XOR of numbers 1 to N and then XOR of given array. After that, XOR of both the results will give the result.

**Find subarray with given sum**

**Approach 1: Start from i=0, move right adding the sum. If sum becomes > requisite start remove trailing elements by doing start++ with the given condition that start < i-1.**

**Approach 2: Start from i=0 and cur\_sum=a[0]; Now keep adding cur\_sum += a[i]; in map with pair<cur\_sum, index>. After each addition check if (cur\_sum-sum) exists in map. If it is then (cur\_index-searched\_index) will give us the range.**

**Dutch National Flag algorithm**

void sort012(int a[], int arr\_size)

{

int lo = 0;

int hi = arr\_size - 1;

int mid = 0;

while (mid <= hi)

{

switch (a[mid])

{

case 0:

swap(&a[lo++], &a[mid++]);

break;

case 1:

mid++;

break;

case 2:

swap(&a[mid], &a[hi--]);

break;

}

}

}

**Equilibrium point in array:**

for( i = 0; i < n; ++i)

{

sum -= arr[i]; // sum is now right sum for index i

if(leftsum == sum)

return i;

leftsum += arr[i];

}

**Maximum Sum Increasing Subsequence**

Let the input array be A. Take another array MSIS with same size as that of A and initialize all its elements as the contents of A.

Take 2 loops and for each position, check if sum of MSIS[j] + MSIS[i] > MSIS[i] and A[i] > A[j]. At last find the max in MSIS array

Below is the main loop::

for ( i = 1; i < n; i++ )

for ( j = 0; j < i; j++ )

if ( arr[i] > arr[j] && msis[i] < msis[j] + arr[i])

msis[i] = msis[j] + arr[i];

**Note: You can also store the elements of MSIS using another vector <vector<int>> which for each ith position, add element to vector**

**Minimum number of platforms needed for trains:**

**Solution:** Sort arrays of both arrival and departure time by storing them both in another array. Now scan through the array. Take counter = 0 and max = 0.

For each arrival, counter++ and for each departure counter--. For each step, check if counter > max then, max = counter

**Chocolates distribution – array of size ‘n’ Each entry represents number of chocolates in packet and it has to be distributed among ‘m’ students with the condition that difference between max and min is minimum.**

**Solution:** Sort the array (of n integers). We have to find the minimum of (max\_in\_window – min\_in\_window) as i = 0 to i+m and then ++i

Find the min. difference in this window starting from I = 0 to i+m-1

**Stock Buy Sell to Maximize Profit**

**Solution:** The cost of a stock on each day is given in an array, find the max profit that you can make by buying and selling in those days.

Solution: We have to find max difference here. So start from i=0 and find minimum by traversing till arr[i+1]<arr[i] which will give use the local minima. Let new state be t = i. Then starting from t move while(arr[t+1]>arr[t]) this will give us maxima. Store the both and set i = t+1 to move over again.

**To find the kth smallest or largest element**

**Solution:** You can use either min-max-heap or quickselect algorithm.

**To find non-repeating element in a sorted array in O(logn)**

**Solution:** All numbers before that unique element have their first occurrence at even indices (0, 2, 4 …) and after that unique number at odd indices (1, 3, 5, …) because of disruption in sequence by that number. Using this property we can find the number such as if our index is even, then check if next is same number as the present one. If yes, that unique number exists on RHS of that index or LHS of that index.

**To find Pythagoras triplet in an array:**

* **Do square of each element O(n)**
* **Sort all elements (O(nlogn)**
* **Use 2 loops to find 2 numbers whose sum is a number currently under consideration**

**Find trapped rain water**

Given is an array which specifies the tower size. Find the volume of water that can be stored in vacant area.

Take two arrays. Store left\_max to store max. tower on left and array right\_max to store the size of maximum tower.

For each index location, do

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

water += min(left[i],right[i]) - arr[i];

**Search in a row wise and column wise sorted matrix**

Start from top right. In case number is < e[i] go left else if number is > current number, go down else return the number.

**LCS(Longest Common Subsequence)**

/\* Returns length of LCS for X[0..m-1], Y[0..n-1] \*/

int lcs( char \*X, char \*Y, int m, int n )

{

if (m == 0 || n == 0)

return 0;

if (X[m-1] == Y[n-1])

return 1 + lcs(X, Y, m-1, n-1);

else

return max(lcs(X, Y, m, n-1), lcs(X, Y, m-1, n));

}

**3-Sum zero**

Find all triplets in an array so that sum of those 3 is 0.

Approach:

> Sort the array

> Use 2 loops, if sum < 0, ++j else –k;

> Add all such triplets to vector<vector<int>>

**Minimize absolute difference among 3 sorted array**

Solution:

Find max and min among 3 elements of each array. Then, depending upon whose value is min, increment the index.

**Notes:**

**> When questions demands using 2 pointers and starting 1 pointer from left and 1 from right is not obvious choice, try starting from beginning.**

**Stacks**

Design a stack that supports pop(), push() and getMin() in O(1) time and O(1) space

Solution:

**Push(x)** – if stack is empty, insert x at the top of stack

If stack is not empty, compare x with minElement. If x is greater than or equal to minElement, simply insert x. If x is less than minElement, insert (2\*x – minElement) into the stack and make minElement equal to x. For example, let previous minElement was 3. Now we want to insert 2. We update minElement as 2 and insert 2\*2 – 3 = 1 into the stack.

**Pop()** : Removes an element from top of stack.

Remove element from top. Let the removed element be y. Two cases arise:

If y is greater than or equal to minElement, the minimum element in the stack is still minElement.

If y is less than minElement, the minimum element now becomes (2\* minElement – y), so update (minElement = 2\* minElement – y). This is where we retrieve previous minimum from current minimum and its value in stack. For example, let the element to be removed be 1 and minElement be 2. We remove 1 and update minElement as 2\*2 – 1 = 3.

**Queue**

**Find the first non-repeating character from stream of characters:**

**Solution:** We need 3 data structures:

* A DLL of characters
* An array inDLL[256] which will maintain pointers to nodes in DLL, initially it will be filled with NULL values.
* An array repeated[256] which will check if a given character is repeated >2 times.

When an element is encountered:

Check value of inDLL[i] and repeated[i]

Case 1: If inDLL[i] is NULL and repeated[i] is false, then we are encountering the character for the 1st time, create a node, add it to DLL, store its pointer in inDLL, repeated will still be false.

Case 2: If value of repeated is false, but inDLL[i] != NULL, then do repeated[i] is true and remove its entry from DLL and set inDLL[i] to NULL

Case 3: If repeated[i] is true and inDLL[i] is NULL, ignore the character.

**Graphs**

A graph is a data structure which represents a mash of interconnected components. The abstract components are termed as vertices while the connection between them are called edges.

Mathematically, a graph is represented as G(V, E) where V denotes the set of vertices while E denotes the set of edges, each edge being represented in the form of (u, v) where ‘u’ and ‘v’ are starting and ending vertex respectively.

**Representation:**

A general graph can be represented either in the form of adjacency matrix or in the form of adjacency list. Adjacency matrix consumes a lot of space in case graph is sparse, but in case graph is dense, it is efficient.

There are two basic operations that are performed on graphs viz.

Breadth-first search and

Depth-first search

For breadth-first, we use queue while for depth-first search, we use stack.

**Detecting cycle in graph:**

A Graph has cycle if there is a back-edge. When we are traversing the graph through DFS, we keep on inserting graph nodes in stack. While traversing, if we visit a vertex which is already in stack, then there exists a cycle.

We’ll use an array recStack[] which will record the items currently inside the stack. We will do recStack[i] = true; for each function entry of a particular vertex ‘i’.While traversing, child of A particular node if we encounter recStack[i] = true;, then there exists a cycle.

// This function is a variation of DFSUytil() in

bool Graph::isCyclicUtil(int v, bool visited[], bool \*recStack)

{

if(visited[v] == false)

{

// Mark the current node as visited and part of recursion stack

visited[v] = true;

recStack[v] = true;

// Recur for all the vertices adjacent to this vertex

list<int>::iterator i;

for(i = adj[v].begin(); i != adj[v].end(); ++i)

{

if ( !visited[\*i] && isCyclicUtil(\*i, visited, recStack) )

return true;

else if (recStack[\*i])

return true;

}

}

recStack[v] = false; // remove the vertex from recursion stack

return false;

}

**Topological sort of a graph:**

Topological sort of graph is order of vertices of a graph such that for every edge (u, v) in a graph, ‘u’ will always come before ‘v’

To find TS of a graph, we use two data structures – a stack and a set. Stack is used to store the result while set is used to maintain set of visited vertices.

The core of topological sort of graph is depth-first traversal. First, we pick any node and call a DFS recursive method to traverse over the children of that node which in turn make recursive call to their children. After we have traversed all children of a given node, we will put that node in stack.

// call DFS for each vertex and push the node in stack after all its // children are visited

void Graph::dfsWithStack(int vertex) {

marked[vertex] = true;

vector<int> vect = graphVector[vertex];

for(int w : vect) {

if(!marked[w]) {

dfsWithStack(w);

}

}

reverse.push(vertex);

}

void Graph::topSort() {

// Call DFS for all vertices…

for(int i = 0; i < vertexCount; ++i) {

if(!marked[i]) {

dfsWithStack(i);

}

}

// At last print the stack..

while(!reverse.empty()){

cout<<", "<<reverse.top()<<", ";

reverse.pop();

}

}

**Minimum Spanning tree:**

Minimum spanning tree or, in short, MST, is a subset of graph which contains all the vertices and in which the sum of weights of all edges is minimum. There are 2 famous algorithms to solve this problem:

**Kruskal Algorithm** : In kruskal algorithm, we use disjoint sets. One set containing all vertices which are visited in MST and other set contains yet to be visited vertices.

Steps:

> Create V sets, V being the number of vertices

> Sort all edges in increasing order of weights by using custom comparator. This step takes O(ElogE) time.

> Traverse all the edges

> for each edge, check if two extremes of that edge are present in same disjoint sets, if they are, ignore them, else, merge those 2 disjoint sets.

> Repeat the above step, till only 1 set remains.

**Prim’s Algorithm:** Prim’s algorithm is another such algorithm to find minimum spanning tree just like Kruskal algorithm. This algorithm is similar to the Dijkstra algorithm. In this algorithm, we maintain 2 sets, 1st set contains the vertices which are included in the MST and 2nd set contains the vertices which are yet to be included in MST.

In this algorithm, at each step, we pick an edge (u, v) whose weight is minimum among all the edges directed from M->N, where M represents the set containing all vertices included in MST and N represents the set containing the vertices yet to be included in MST. To pick this minimum, we will use binary heap. The binary heap will contains entries all the vertices not yet included in MST where each entry is represented as a pair (vertex, value) where ‘value’ is the current minimum weight of vertex incident on that vertex.

Steps

> Put all vertices in binary heap with their value as as infinity. Set the value of source vertex as 0.

> Now, do the following till binary heap is empty

> Pop-out the vertex with the minimum value (extract-min) operation) from binary heap and add that to the set M and update the values of all vertices in binary heap which are adjacent to popped up vertex.

**Dijkstra algorithm** – It is a single source shortest path algorithm which determines the minimum distance of all vertices from a given source. The logic is similar to what is used in Prim’s algorithm

We maintain the following data structures:

> A heap (To sort vertices based on their weights) Each heap entry is a kind of map <vertex\_id, distance>

> A map <node, parent\_of\_node> to store path to a given node.

> A map <node, distance> which represents the visited set, or the nodes which have been included in the solution.

Initially, we will put all vertices with weights set to INT\_MAX in binary heap. We will set weight of source vertex to 0 in heap and extract that out.

Now, do the following till heap is empty

* Do extract-min and pick the node with lowest weight, add that to visited set.
* Update all its adjacent vertices which are present in heap (Don’t touch the ones present in visited set) depending upon if the calculated weight is lesser than the current vertex weight.

**Difference between Prim and Dijkstra:**

The only difference I see is that Prim's algorithm stores a minimum cost edge whereas Dijkstra's algorithm stores the total cost from a source vertex to the current vertex.

So, if you want to deploy a train to connect several cities, you would use Prim's algorithm But if you want to go from one city to other saving as much time as possible, you'd use Dijkstra's algorithm.

**Shortest path in a Binary Maze**: In this, we have to find the shortest path from a given cell of a maze to another cell. A maze is represented in the form of matrix of 0’s and 1’s and cell is denoted by the coordinate which contains 1.

Solution:

We can solve this problem using Lee’s algorithm which deploys Breadth-first search to find the result. Here in, a queue of nodes is used in which each node is represented by endpoints and a variable ‘dst’ that will store the distance of that cell from the source vertex.

Shortest path in snake and ladder game: <Similar to above algorithm>

Minimum Cost Path with Left, Right, Bottom and Up moves allowed

Here also, we can use Lee’s algorithm wherein BFS is used. We will another 2-D array dist[M][N] which will store the minimum distance between that node and start node.

Solution:

> Push start node in queue.

> Do the following til queue is not empty

> Pop the node and update its adjacent nodes by checking the distance so as to pick the minimum

Code as below:

while (!st.empty())

{

// get the cell with minimum distance and delete

// it from the set

cell k = \*st.begin();

st.erase(st.begin());

// looping through all neighbours

for (int i = 0; i < 4; i++)

{

int x = k.x + dx[i];

int y = k.y + dy[i];

// if not inside boundry, ignore them

if (!isInsideGrid(x, y))

continue;

// If distance from current cell is smaller, then

// update distance of neighbour cell

if (dis[x][y] > dis[k.x][k.y] + grid[x][y])

{

// If cell is already there in set, then

// remove its previous entry

if (dis[x][y] != INT\_MAX)

st.erase(st.find(cell(x, y, dis[x][y])));

// update the distance and insert new updated

// cell in set

dis[x][y] = dis[k.x][k.y] + grid[x][y];

st.insert(cell(x, y, dis[x][y]));

}

}

}

Strongly Connected Component: SCC of a graph refers to the subgraph/tree of the given graph such that each vertex ‘v’ in subgraph is reachable from remaining vertices of subgraph.

Solution: SCC can be extracted by using Kosaraju’s algorithm.

> Do DFS of graph and store the vertices of graph in stack in order of their finishing times. Put stack.push() after

for(auto a:children)

> Reverse(Transpose) the graph

> Now, again do DFS by parsing through the stack entries and running them over the transposed graph.

Given a sorted dictionary of an alien language, find order of characters.

Solution: The main idea is to create a graph using the characters of string and do topological sort.

> Create a graph g with number of vertices equal to the size of alphabet in the given alien language. For example, if the alphabet size is 5, then there can be 5 characters in words. Initially there are no edges in graph.

> Do following for every pair of adjacent words in given sorted array.

…..a) Let the current pair of words be word1 and word2. One by one compare characters of both words and find the first mismatching characters.

…..b) Create an edge in g from mismatching character of word1 to that of word2.

> Print topological sorting of the above created graph.

**Check if array of strings can be chained to form circle**

A string X can be put before another string Y in circle if the last character of X is same as first character of Y.

Solution:

> Treat start and end character of string as vertex of graph which are connected via an edge.

> Create a graph by connecting two end points of string via an edge.

> For solution to be valid, the graph must contains the loop which can be depicted only if graph is SCC (i.e. all vertices are reachable from a given vertex in graph) and in/out-degrees of all vertices is same.

**Notes:**

BFS can only be used to find shortest distance in an unweighted graph like a mesh or maze. For a weighed graph you may need Dijkstra's algorithm or Bellmann-Ford's algorithm.

Consider a graph like this:

A------(3)-----------B

| |

\--(1)----C-------(1)/

The shortest path from A to B is via C (with a total weight of 2). A normal BFS will take the path directly from A to B, marking B as seen, and A to C, marking C as seen.

> We can use BFS to find the shortest path in weighted graph, but we need to replace each weighted nodes with nodes at unit distance.

> To find the minimum cost from source to destination in M X N grid, use dijkstra algorithm.

> A vertex in an undirected connected graph is an articulation point (or cut vertex) iff removing it (and edges through it) disconnects the graph

**Dynamic Programming**

Given an array of non-negative integers, you are initially positioned at the first index of the array.

Each element in the array represents your maximum jump length at that position.

Determine if you are able to reach the last index.

Solution: This can be done using dynamic programming starting from the end. Maintain the minimum index from where we can reach to the destination.

for (int i = n - 2; i >= 0; i--) {

bool isPossibleFromThisIndex = false;

if (i + A[i] >= minIndexPossible) {

isPossibleFromThisIndex = true;

minIndexPossible = i;

}

if (i == 0) return isPossibleFromThisIndex;

}

Find max non-contiguous sequence of numbers

If size == 1 return first element

Else if size == 2, return max of first 2 elements

Else if size == 3, return max (e[2]+e[0], e[1])

Else res[i] += max(res[i-2], res[i-3]);

Find path with minimum sum in matrix wherein we can go down and right

Either create a new 2-D matrix or keep the current one and traverse over the whole matrix with each position = minimum of [i-1][j] and [i][j-1] keeping into account the boundary conditions. At last, return array[m-1][n-1]

Longest increasing and decreasing sequence

Maintain 2 arrays inc[n] and dec[n] find common point where inc[i]+dec[i]-1 is mzximum.

Given a string, find if there is any sub-sequence that repeats itself.

iFor this problem, you only need to find a subsequence of 2 chars which is repeated in that string. For that, you can use unordered\_map<string, pair<int, int> >.

For each pair, if it doesn’t exist, insert else check its <I,j> if it’s different, you are good to go.

Notes:  
> Not necessarily you need to maintain a result array. You can play with indices.

>