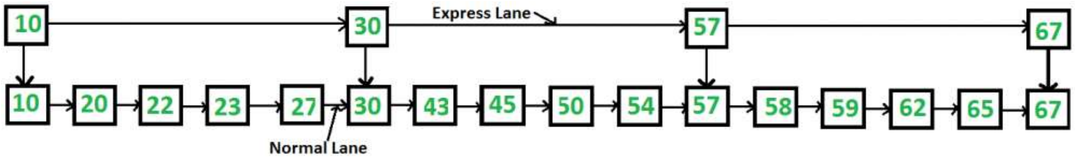
Skip List | Set 1 (Introduction)

Can we search in a sorted linked list in better than O(n) time?

The worst case search time for a sorted linked list is O(n) as we can only linearly traverse the list and cannot skip nodes while searching. For a Balanced Binary Search Tree, we skip almost half of the nodes after one comparison with root. For a sorted array, we have random access and we can apply Binary Search on arrays.

Can we augment sorted linked lists to make the search faster? The answer is Skip List. The idea is simple, we create multiple layers so that we can skip some nodes. See the following example list with 16 nodes and two layers. The upper layer works as an "express lane" which connects only main outer stations, and the lower layer works as a "normal lane" which connects every station. Suppose we want to search for 50, we start from first node of "express lane" and keep moving on "express lane" till we find a node whose next is greater than 50. Once we find such a node (30 is the node in following example) on "express lane", we move to "normal lane" using pointer from this node, and linearly search for 50 on "normal lane". In following example, we start from 30 on "normal lane" and with linear search, we find 50.



What is the time complexity with two layers? The worst case time complexity is number of nodes on "express lane" plus number of nodes in a segment (A segment is number of "normal lane" nodes between two "express lane" nodes) of "normal lane". So if we have n nodes on "normal lane", √n (square root of n) nodes on "express lane" and we equally divide the "normal lane", then there will be √n nodes in every segment of "normal lane" . √n is actually optimal division with two layers. With this arrangement, the number of nodes traversed for a search will be O(√n). Therefore O(√n) extra space, we are able to reduce the time complexity to O(√n).

Skip List | Set 2 (Insertion)

We have already discussed the idea of Skip list and how they work in Skip List | Set 1 (Introduction). In this article, we will be discussing how to insert an element in Skip list.

Deciding nodes level

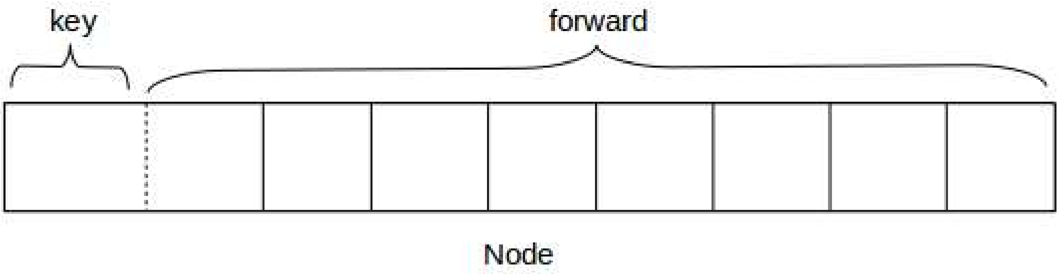
Each element in the list is represented by a node, the level of the node is chosen randomly while insertion in the list. **Level does not depend on the number of elements in the node.** The level for node is decided by the following algorithm –

```
randomLevel()
lvl := 1
//random() that returns a random value in [0...1)
while random() < p and lvl < MaxLevel do
    lvl := lvl + 1
return lvl
```

MaxLevel is the upper bound on number of levels in the skip list. It can be determined as – $L(N) = log_{p/2}N$. Above algorithm assure that random level will never be greater than MaxLevel. Here **p** is the fraction of the nodes with level **i** pointers also having level **i+1** pointers and N is the number of nodes in the list.

Node Structure

Each node carries a key and a **forward** array carrying pointers to nodes of a different level. A level i node carries i forward pointers indexed through 0 to i.



Insertion in Skip List

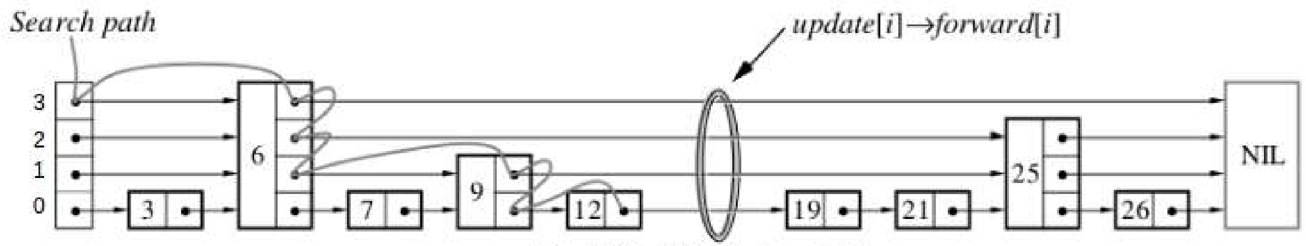
We will start from highest level in the list and compare key of next node of the current node with the key to be inserted. Basic idea is If –

1. Key of next node is less than key to be inserted then we keep on moving forward on the same level
2. Key of next node is greater than the key to be inserted then we store the pointer to current node **i** at **update[i]** and move one level down and continue our search.

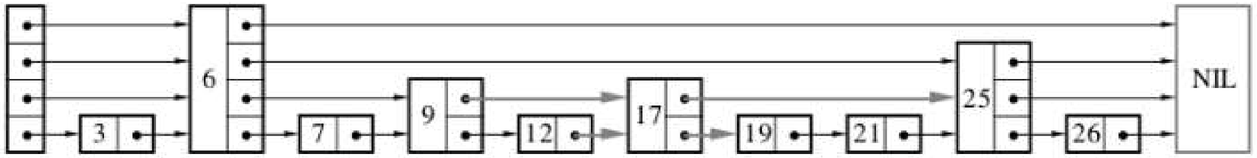
At the level 0, we will definitely find a position to insert given key. Following is the psuedo code for the insertion algorithm –

```
Insert(list, searchKey)
local update[0...MaxLevel+1]
x := list -> header
for i := list -> level downto 0 do
    while x -> forward[i] -> key  forward[i]
update[i] := x
x := x -> forward[0]
lvl := randomLevel()
if lvl > list -> level then
for i := list -> level + 1 to lvl do
    update[i] := list -> header
    list -> level := lvl
x := makeNode(lvl, searchKey, value)
for i := 0 to level do
    x -> forward[i] := update[i] -> forward[i]
    update[i] -> forward[i] := x
```

Here update[i] holds the pointer to node at level **i** from which we moved down to level **i-1** and pointer of node left to insertion position at level 0. Consider this example where we want to insert key 17 –



original list, 17 to be inserted



list after insertion, updated pointers in grey

Level	0	1	2	3
Pointer	12	6	6	6

update array

Following is the code for insertion of key in Skip list –

```
// C++ code for inserting element in skip list

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

// Class to implement node
class Node
{
public:
    int key;

    // Array to hold pointers to node of different level
    Node **forward;
    Node(int, int);
};

Node::Node(int key, int level)
{
    this->key = key;

    // Allocate memory to forward
    forward = new Node*[level+1];

    // Fill forward array with 0(NULL)
    memset(forward, 0, sizeof(Node*)*(level+1));
};

// Class for Skip list
class SkipList
{
    // Maximum level for this skip list
    int MAXLVL;
    // P is the fraction of the nodes with level
    // i pointers also having level i+1 pointers
    float P;

    // current level of skip list
    int level;

    // pointer to header node
    Node *header;
public:
    SkipList(int, float);
    int randomLevel();
    Node* createNode(int, int);
    void insertElement(int);
    void displayList();
};

SkipList::SkipList(int MAXLVL, float P)
{
    this->MAXLVL = MAXLVL;
    this->P = P;
    level = 0;

    // create header node and initialize key to -1
    header = new Node(-1, MAXLVL);
};

// create random level for node
int SkipList::randomLevel()
{
    float r = (float)rand()/RAND_MAX;
    int lvl = 0;
    while (r < P && lvl < MAXLVL)
    {
        lvl++;
        r = (float)rand()/RAND_MAX;
    }
    return lvl;
};

// create new node
Node* SkipList::createNode(int key, int level)
{
    Node *n = new Node(key, level);
    return n;
};

// Insert given key in skip list
void SkipList::insertElement(int key)
{
    Node *current = header;

    // create update array and initialize it
    Node *update[MAXLVL+1];
    memset(update, 0, sizeof(Node*)*(MAXLVL+1));

    /*    start from highest level of skip list
        move the current pointer forward while key
        is greater than key of node next to current
        Otherwise inserted current in update and
        move one level down and continue search
    */
    for (int i = level; i >= 0; i--)
    {
        while (current->forward[i] != NULL &&
              current->forward[i]->key < key)
            current = current->forward[i];
        update[i] = current;
    }
    /* reached level 0 and forward pointer to
       right, which is desired position to
       insert key.
    */
    current = current->forward[0];

    /* if current is NULL that means we have reached
       to end of the level or current's key is not equal
       to key to insert that means we have to insert
       node between update[0] and current node */
    if (current == NULL || current->key != key)
    {
        // Generate a random level for node
        int rlevel = randomLevel();

        // If random level is greater than list's current
        // level (node with highest level inserted in
        // list so far), initialize update value with pointer
        // to header for further use
        if (rlevel > level)
        {
            for (int i=level+1;i<rlevel+1;i++)
                update[i] = header;

            // Update the list current level
            level = rlevel;
        }

        // create new node with random level generated
        Node* n = createNode(key, rlevel);

        // insert node by rearranging pointers
        for (int i=0;i<=rlevel;i++)
        {
            n->forward[i] = update[i]->forward[i];
            update[i]->forward[i] = n;
        }
        cout << "Successfully Inserted key " << key << "\n";
    }
};

// Display skip list level wise
void SkipList::displayList()
{
    cout<<"\n*****Skip List*****"<<"\n";
    for (int i=0;i<=level;i++)
    {
        Node *node = header->forward[i];
        cout << "Level " << i << ": ";
        while (node != NULL)
        {
            cout << node->key<<" ";
            node = node->forward[i];
        }
        cout << "\n";
    }
};

// Driver to test above code
int main()
{
    // Seed random number generator
    srand((unsigned)time(0));

    // create SkipList object with MAXLVL and P
    SkipList lst(3, 0.5);

    lst.insertElement(3);
    lst.insertElement(6);
    lst.insertElement(7);
    lst.insertElement(9);
    lst.insertElement(12);
    lst.insertElement(19);
    lst.insertElement(17);
    lst.insertElement(26);
    lst.insertElement(21);
    lst.insertElement(25);
    lst.displayList();
}
```

Run on IDE

Python

```
# Python3 code for inserting element in skip list

import random

class Node(object):
    '''
    Class to implement node
    '''
    def __init__(self, key, level):
        self.key = key

        # list to hold references to node of different level
        self.forward = [None]*(level+1)

class SkipList(object):
    '''
    Class for Skip list
    '''
    def __init__(self, max_lvl, P):
        # Maximum level for this skip list
        self.MAXLVL = max_lvl

        # P is the fraction of the nodes with level
        # i references also having level i+1 references
        self.P = P

        # create header node and initialize key to -1
        self.header = self.createNode(self.MAXLVL, -1)

        # current level of skip list
        self.level = 0

    # create  new node
    def createNode(self, lvl, key):
        n = Node(key, lvl)
        return n

    # create random level for node
    def randomLevel(self):
        lvl = 0
        while random.random()<self.P and \
              lvl<self.MAXLVL:lvl += 1
        return lvl

    # insert given key in skip list
    def insertElement(self, key):
        # create update array and initialize it
        update = [None]*(self.MAXLVL+1)
        current = self.header

        '''
        start from highest level of skip list
        move the current reference forward while key
        is greater than key of node next to current
        Otherwise inserted current in update and
        move one level down and continue search
        '''
        for i in range(self.level, -1, -1):
            while current.forward[i] and \
                  current.forward[i].key < key:
                current = current.forward[i]
            update[i] = current

        '''
        reached level 0 and forward reference to
        right, which is desired position to
        insert key.
        '''
        current = current.forward[0]

        '''
        if current is NULL that means we have reached
           to end of the level or current's key is not equal
           to key to insert that means we have to insert
           node between update[0] and current node
       '''
        if current == None or current.key != key:
            # Generate a random level for node
            rlevel = self.randomLevel()

            '''
            If random level is greater than list's current
            level (node with highest level inserted in
            list so far), initialize update value with reference
            to header for further use
            '''
            if rlevel > self.level:
                for i in range(self.level+1, rlevel+1):
                    update[i] = self.header
                self.level = rlevel

            # create new node with random level generated
            n = self.createNode(rlevel, key)

            # insert node by rearranging references
            for i in range(rlevel+1):
                n.forward[i] = update[i].forward[i]
                update[i].forward[i] = n

            print("Successfully inserted key {}".format(key))

    # Display skip list level wise
    def displayList(self):
        print("\n*****Skip List******")
        head = self.header
        for lvl in range(self.level+1):
            print("Level {}: ".format(lvl), end=" ")
            node = head.forward[lvl]
            while(node != None):
                print(node.key, end=" ")
                node = node.forward[lvl]
            print("")

# Driver to test above code
def main():
    lst = SkipList(3, 0.5)
    lst.insertElement(3)
    lst.insertElement(6)
    lst.insertElement(7)
    lst.insertElement(9)
    lst.insertElement(12)
    lst.insertElement(19)
    lst.insertElement(17)
    lst.insertElement(26)
    lst.insertElement(21)
    lst.insertElement(25)
    lst.displayList()

main()
```

Run on IDE

Output:

```
Successfully Inserted key 3
Successfully Inserted key 6
Successfully Inserted key 7
Successfully Inserted key 9
Successfully Inserted key 12
Successfully Inserted key 19
Successfully Inserted key 17
Successfully Inserted key 26
Successfully Inserted key 21
Successfully Inserted key 25

*****Skip List*****
Level 0: 3 6 7 9 12 17 19 21 25 26
Level 1: 3 6 12 17 25
Level 2: 6 12 17 25
Level 3: 12 17 25
```

Note: The level of nodes is decided randomly, so output may differ.
Time complexity (Average): $O(logn)$
Time complexity (Worst): $O(n)$
In next article we will discuss searching and deletion in Skip List.
References

- ftp://ftp.cs.umd.edu/pub/skipLists/skiplists.pdf

This article is contributed by **Atul Kumar**. If you like GeeksforGeeks and would like to contribute, you can also write an article using contribute.geeksforgeeks.org or mail your article to contribute@geeksforgeeks.org. See your article appearing on the GeeksforGeeks main page and help other Geeks.

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Skip List | Set 3 (Searching and Deletion)

In previous article Skip List | Set 2 (Insertion) we discussed the structure of skip nodes and how to insert an element in the skip list. In this article we will discuss how to search and delete an element from skip list.

Searching an element in Skip list

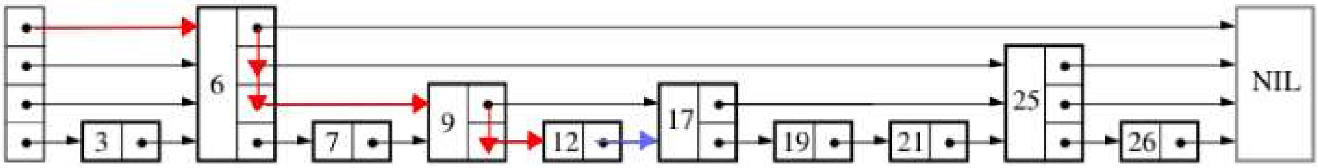
Searching an element is very similar to approach for searching a spot for inserting an element in Skip list. The basic idea is if –

1. Key of next node is less than search key then we keep on moving forward on the same level.
2. Key of next node is greater than the key to be inserted then we store the pointer to current node **i** at **update[i]** and move one level down and continue our search.

At the lowest level (0), if the element next to the rightmost element (update[0]) has key equal to the search key, then we have found key otherwise failure.
Following is the pseudo code for searching element –

```
Search(list, searchKey)
x := list -> header
-- loop invariant: x -> key  level downto 0 do
    while x -> forward[i] -> key  forward[i]
x := x -> forward[0]
if x -> key = searchKey then return x -> value
else return failure
```

Consider this example where we want to search for key 17-



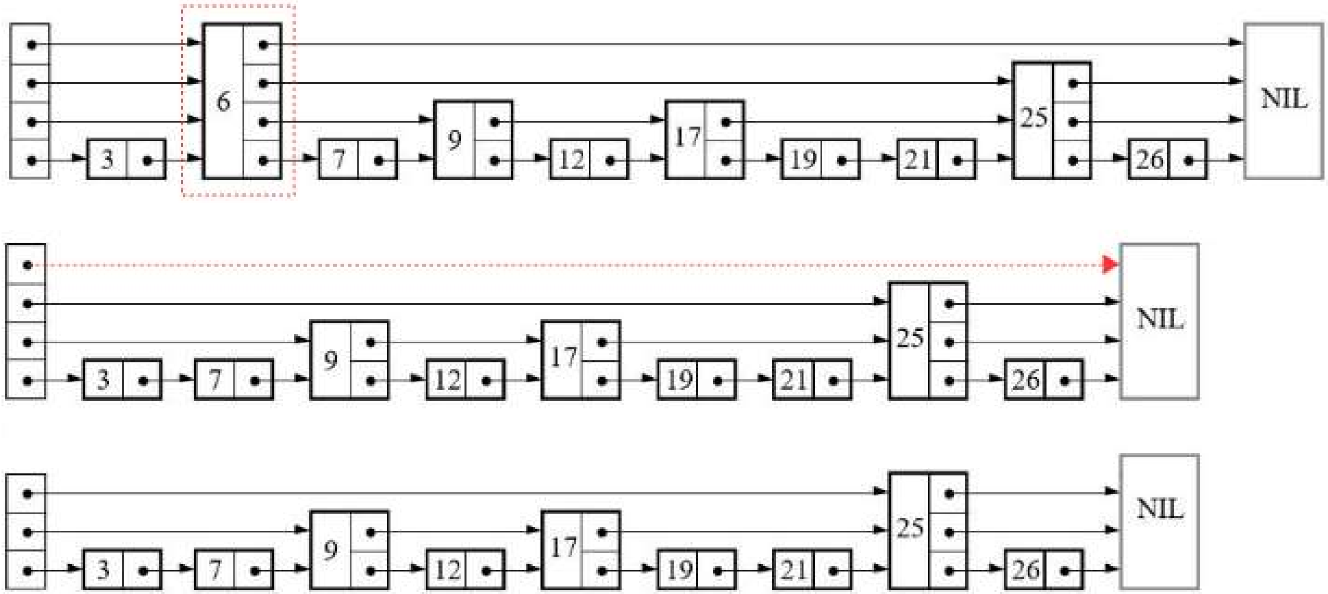
Deleting an element from the Skip list

Deletion of an element k is preceded by locating element in the Skip list using above mentioned search algorithm. Once the element is located, rearrangement of pointers is done to remove element form list just like we do in singly linked list. We start from lowest level and do rearrangement until element next to update[i] is not k.

After deletion of element there could be levels with no elements, so we will remove these levels as well by decrementing the level of Skip list. Following is the pseudo code for deletion –

```
Delete(list, searchKey)
local update[0..MaxLevel+1]
x := list -> header
for i := list -> level downto 0 do
    while x -> forward[i] -> key  forward[i]
    update[i] := x
x := x -> forward[0]
if x -> key = searchKey then
    for i := 0 to list -> level do
        if update[i] -> forward[i] ≠ x then break
        update[i] -> forward[i] := x -> forward[i]
    free(x)
    while list -> level > 0 and list -> header -> forward[list -> level] = NIL do
        list -> level := list -> level – 1
```

Consider this example where we want to delete element 6 –



Here at level 3, there is no element (arrow in red) after deleting element 6. So we will decrement level of skip list by 1.

Following is the code for searching and deleting element from Skip List –

```
// C++ code for searching and deleting element in skip list

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

// Class to implement node
class Node
{
public:
    int key;

    // Array to hold pointers to node of different level
    Node **forward;
    Node(int, int);
};

Node::Node(int key, int level)
{
    this->key = key;

    // Allocate memory to forward
    forward = new Node*[level+1];

    // Fill forward array with 0(NULL)
    memset(forward, 0, sizeof(Node*)*(level+1));
};

// Class for Skip list
class SkipList
{
    // Maximum level for this skip list
    int MAXLVL;

    // P is the fraction of the nodes with level
    // i pointers also having level i+1 pointers
    float P;

    // current level of skip list
    int level;

    // pointer to header node
    Node *header;
public:
    SkipList(int, float);
    int randomLevel();
    Node* createNode(int, int);
    void insertElement(int);
    void deleteElement(int);
    void searchElement(int);
    void displayList();
};

SkipList::SkipList(int MAXLVL, float P)
{
    this->MAXLVL = MAXLVL;
    this->P = P;
    level = 0;

    // create header node and initialize key to -1
    header = new Node(-1, MAXLVL);
};

// create random level for node
int SkipList::randomLevel()
{
    float r = (float)rand()/RAND_MAX;
    int lvl = 0;
    while(r < P && lvl < MAXLVL)
    {
        lvl++;
        r = (float)rand()/RAND_MAX;
    }
    return lvl;
};

// create new node
Node* SkipList::createNode(int key, int level)
{
    Node *n = new Node(key, level);
    return n;
};

// Insert given key in skip list
void SkipList::insertElement(int key)
{
    Node *current = header;

    // create update array and initialize it
    Node *update[MAXLVL+1];
    memset(update, 0, sizeof(Node*)*(MAXLVL+1));

    /*    start from highest level of skip list
        move the current pointer forward while key
        is greater than key of node next to current
        Otherwise inserted current in update and
        move one level down and continue search
    */
    for(int i = level; i >= 0; i--)
    {
        while(current->forward[i] != NULL &&
              current->forward[i]->key < key)
            current = current->forward[i];
        update[i] = current;
    }

    /* reached level 0 and forward pointer to
       right, which is desired position to
       insert key.
    */
    current = current->forward[0];

    /* if current is NULL that means we have reached
       to end of the level or current's key is not equal
       to key to insert that means we have to insert
       node between update[0] and current node */
    if (current == NULL || current->key != key)
    {
        // Generate a random level for node
        int rlevel = randomLevel();

        /* If random level is greater than list's current
           level (node with highest level inserted in
           list so far), initialize update value with pointer
           to header for further use */
        if(rlevel > level)
        {
            for(int i=level+1;i<rlevel+1;i++)
                update[i] = header;

            // Update the list current level
            level = rlevel;
        }

        // create new node with random level generated
        Node* n = createNode(key, rlevel);
        // insert node by rearranging pointers
        for(int i=0;i<=rlevel;i++)
        {
            n->forward[i] = update[i]->forward[i];
            update[i]->forward[i] = n;
        }
        cout<<"Successfully Inserted key "<<key<<"\n";
    }
};

// Delete element from skip list
void SkipList::deleteElement(int key)
{
    Node *current = header;

    // create update array and initialize it
    Node *update[MAXLVL+1];
    memset(update, 0, sizeof(Node*)*(MAXLVL+1));

    /*    start from highest level of skip list
        move the current pointer forward while key
        is greater than key of node next to current
        Otherwise inserted current in update and
        move one level down and continue search
    */
    for(int i = level; i >= 0; i--)
    {
        while(current->forward[i] != NULL  &&
              current->forward[i]->key < key)
            current = current->forward[i];
        update[i] = current;
    }

    /* reached level 0 and forward pointer to
       right, which is possibly our desired node.*/
    current = current->forward[0];

    // If current node is target node
    if(current != NULL and current->key == key)
    {
        /* start from lowest level and rearrange
           pointers just like we do in singly linked list
           to remove target node */
        for(int i=0;i<=level;i++)
        {
            /* If at level i, next node is not target
               node, break the loop, no need to move
              further level */
            if(update[i]->forward[i] != current)
                break;

            update[i]->forward[i] = current->forward[i];
        }

        // Remove levels having no elements
        while(level>0 &&
              header->forward[level] == 0)
            level--;
         cout<<"Successfully deleted key "<<key<<"\n";
    }
};

// Search for element in skip list
void SkipList::searchElement(int key)
{
    Node *current = header;

    /*    start from highest level of skip list
        move the current pointer forward while key
        is greater than key of node next to current
        Otherwise inserted current in update and
        move one level down and continue search
    */
    for(int i = level; i >= 0; i--)
    {
        while(current->forward[i] &&
               current->forward[i]->key < key)
            current = current->forward[i];

    }

    /* reached level 0 and advance pointer to
       right, which is possibly our desired node*/
    current = current->forward[0];

    // If current node have key equal to
    // search key, we have found our target node
    if(current and current->key == key)
        cout<<"Found key: "<<key<<"\n";
};

// Display skip list level wise
void SkipList::displayList()
{
    cout<<"\n*****Skip List*****"<<"\n";
    for(int i=0;i<=level;i++)
    {
        Node *node = header->forward[i];
        cout<<"Level "<<i<<": ";
        while(node != NULL)
        {
            cout<<node->key<<" ";
            node = node->forward[i];
        }
        cout<<"\n";
    }
};

// Driver to test above code
int main()
{
    // Seed random number generator
    srand((unsigned)time(0));

    // create SkipList object with MAXLVL and P
    SkipList lst(3, 0.5);

    lst.insertElement(3);
    lst.insertElement(6);
    lst.insertElement(7);
    lst.insertElement(9);
    lst.insertElement(12);
    lst.insertElement(19);
    lst.insertElement(17);
    lst.insertElement(26);
    lst.insertElement(21);
    lst.insertElement(25);
    lst.displayList();

    //Search for node 19
    lst.searchElement(19);

    //Delete node 19
    lst.deleteElement(19);
    lst.displayList();
}
```

Run on IDE

Python

```python
# Python3 code for searching and deleting element in skip list

import random

class Node(object):
    '''
    Class to implement node
    '''
    def __init__(self, key, level):
        self.key = key

        # list to hold references to node of different level
        self.forward = [None]*(level+1)

class SkipList(object):
    '''
    Class for Skip list
    '''
    def __init__(self, max_lvl, P):
        # Maximum level for this skip list
        self.MAXLVL = max_lvl

        # P is the fraction of the nodes with level
        # i references also having level i+1 references
        self.P = P

        # create header node and initialize key to -1
        self.header = self.createNode(self.MAXLVL, -1)

        # current level of skip list
        self.level = 0

    # create  new node
    def createNode(self, lvl, key):
        n = Node(key, lvl)
        return n

    # create random level for node
    def randomLevel(self):
        lvl = 0
        while random.random()<self.P and \
              lvl<self.MAXLVL:lvl += 1
        return lvl

    # insert given key in skip list
    def insertElement(self, key):
        # create update array and initialize it
        update = [None]*(self.MAXLVL+1)
        current = self.header

        '''
        start from highest level of skip list
        move the current reference forward while key
        is greater than key of node next to current
        Otherwise inserted current in update and
        move one level down and continue search
        '''
        for i in range(self.level, -1, -1):
            while current.forward[i] and \
                  current.forward[i].key < key:
                current = current.forward[i]
            update[i] = current

        '''
        reached level 0 and forward reference to
        right, which is desired position to
        insert key.
        '''
        current = current.forward[0]

        '''
        if current is NULL that means we have reached
           to end of the level or current's key is not equal
           to key to insert that means we have to insert
           node between update[0] and current node
       '''
        if current == None or current.key != key:
            # Generate a random level for node
            rlevel = self.randomLevel()

            '''
            If random level is greater than list's current
            level (node with highest level inserted in
            list so far), initialize update value with reference
            to header for further use
            '''
            if rlevel > self.level:
                for i in range(self.level+1, rlevel+1):
                    update[i] = self.header
                self.level = rlevel

            # create new node with random level generated
            n = self.createNode(rlevel, key)

            # insert node by rearranging references
            for i in range(rlevel+1):
                n.forward[i] = update[i].forward[i]
                update[i].forward[i] = n

            print("Successfully inserted key {}".format(key))

    def deleteElement(self, search_key):

        # create update array and initialize it
        update = [None]*(self.MAXLVL+1)
        current = self.header

        '''
        start from highest level of skip list
        move the current reference forward while key
        is greater than key of node next to current
        Otherwise inserted current in update and
        move one level down and continue search
        '''
        for i in range(self.level, -1, -1):
            while(current.forward[i] and \
                  current.forward[i].key < search_key):
                current = current.forward[i]
            update[i] = current

        '''
        reached level 0 and advance reference to
        right, which is prssibly our desired node
        '''
        current = current.forward[0]

        # If current node is target node
        if current != None and current.key == search_key:

            '''
            start from lowest level and rearrange references
            just like we do in singly linked list
            to remove target node
            '''
            for i in range(self.level+1):
                '''
                If at level i, next node is not target
                node, break the loop, no need to move
                further level
                '''
                if update[i].forward[i] != current:
                    break
                update[i].forward[i] = current.forward[i]

            # Remove levels having no elements
            while(self.level>0 and\
                  self.header.forward[self.level] == None):
                self.level -= 1
            print("Successfully deleted {}".format(search_key))

    def searchElement(self, key):
        current = self.header

        '''
        start from highest level of skip list
        move the current reference forward while key
        is greater than key of node next to current
        Otherwise inserted current in update and
        move one level down and continue search
        '''
        for i in range(self.level, -1, -1):
            while(current.forward[i] and\
                  current.forward[i].key < key):
                current = current.forward[i]

        # reached level 0 and advance reference to
        # right, which is prssibly our desired node
        current = current.forward[0]

        # If current node have key equal to
        # search key, we have found our target node
        if current and current.key == key:
            print("Found key ", key)

    # Display skip list level wise
    def displayList(self):
        print("\n*****Skip List******")
        head = self.header
        for lvl in range(self.level+1):
            print("Level {}: ".format(lvl), end=" ")
            node = head.forward[lvl]
            while(node != None):
                print(node.key, end=" ")
                node = node.forward[lvl]
            print("")

# Driver to test above code
def main():
    lst = SkipList(3, 0.5)
    lst.insertElement(3)
    lst.insertElement(6)
    lst.insertElement(7)
    lst.insertElement(9)
    lst.insertElement(12)
    lst.insertElement(19)
    lst.insertElement(17)
    lst.insertElement(26)
    lst.insertElement(21)
    lst.insertElement(25)
    lst.displayList()

    # Search for node 19
    lst.searchElement(19)
    # Delete node 19
    lst.deleteElement(19)
    lst.displayList()

main()
```

Run on IDE

Output:

```
Successfully Inserted key 3
Successfully Inserted key 6
Successfully Inserted key 7
Successfully Inserted key 9
Successfully Inserted key 12
Successfully Inserted key 19
Successfully Inserted key 17
Successfully Inserted key 26
Successfully Inserted key 21
Successfully Inserted key 25

*****Skip List*****
Level 0: 3 6 7 9 12 17 19 21 25 26
Level 1: 3 17 19 21 26
Level 2: 17 19 21
Found key: 19
Successfully deleted key 19

*****Skip List*****
Level 0: 3 6 7 9 12 17 21 25 26
Level 1: 3 17 21 26
Level 2: 17 21
```

Time complexity of both searching and deletion is same –
Time complexity (Average): $O(logn)$
Time complexity (Worst): $O(n)$

References

ftp://ftp.cs.umd.edu/pub/skipLists/skiplists.pdf

This article is contributed by **Atul Kumar**. If you like GeeksforGeeks and would like to contribute, you can also write an article using contribute.geeksforgeeks.org or mail your article to contribute@geeksforgeeks.org. See your article appearing on the GeeksforGeeks main page and help other Geeks.

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