IIT Madras
BSc Degree

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PDSA - Week 3

Quick Sort

Visualization

7 VISUALGO.NET / en /sorting

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Source - https://visualgo.net/en/sorting

Implementation

```
def quicksort(L,l,r): # Sort L[l:r]
    if (r - l <= 1):
        return L
    (pivot,lower,upper) = (L[l],l+1,l+1)
    for i in range(l+1,r):
        if L[i] > pivot: # Extend upper segment
            upper = upper+1
        else: # Exchange L[i] with start of upper segment
            (L[i], L[lower]) = (L[lower], L[i])
            # Shift both segments
            (lower,upper) = (lower+1,upper+1)
```

```
    # Move pivot between lower and upper
    (L[l],L[lower-1]) = (L[lower-1],L[l])
    lower = lower-1
    # Recursive calls
    quicksort(L,l,lower)
    quicksort(L,lower+1,upper)
    return(L)
```

Other Implementation

```
def partition(L,lower,upper):
  # we are selecting first element as a pivot
  pivot = L[lower]
  i = lower
  for j in range(lower+1,upper+1):
    if L[j] <= pivot:
      i += 1
      L[i],L[j] = L[j],L[i]
  L[lower],L[i]= L[i],L[lower]
  #returning the position of pivot
  return i

def quicksort(L,lower,upper):
  if(lower < upper):
    pivot_pos = partition(L,lower,upper);
    # calling the quick sort on leftside part of pivot
    quicksort(L,lower,pivot_pos-1)
    # calling the quick sort on rightside part of pivot
    quicksort(L,pivot_pos+1,upper)
  return L
```

Recurrence relation in best and average case T(n) = 2T(n/2)+ O(n)

Recurrence relation in worst case T(n) = T(n-1)+ O(n)

Analysis

Best Case - $n + n + n...logn\ times = nlogn = O(nlogn)$

Average Case - $n + n + n...logn\ times = nlogn = O(nlogn)$

Worst Case - $n + (n-1) + (n-2)...1 = n(n+1)/2 = O(n^2)$

Stable - No

Sort in Place - Yes

Comparison of sorting algorithm

Parameter	Selection sort	Insertion sort	Merge sort	Quicksort
Best case	$O(n^2)$	$O(n)$	$O(n \log n)$	$O(n \log n)$
Average case	$O(n^2)$	$O(n^2)$	$O(n \log n)$	$O(n \log n)$
Worst case	$O(n^2)$	$O(n^2)$	$O(n \log n)$	$O(n^2)$
In-place	Yes	Yes	No	Yes
Stable	No	Yes	Yes	No

Linked List

The linked list is a collection of elements, where each element points to the next. It is a data structure consisting of a collection of nodes that together represent a sequence.

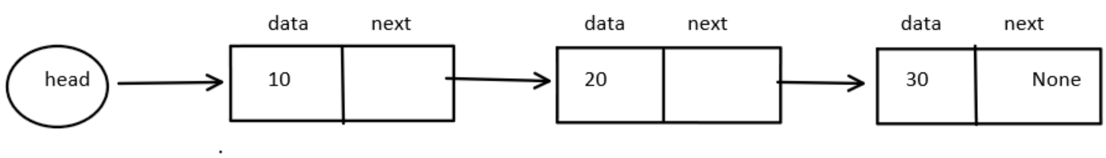
There are two types of linked lists:

- Singly linked list
- Doubly linked list

Singly linked list

- `head` :- Store the reference of the first node. If the list is empty, then it stores `None`
- Each node have two fields:
    - `data` :- Store actual value
    - `next` :- Store reference of the next node

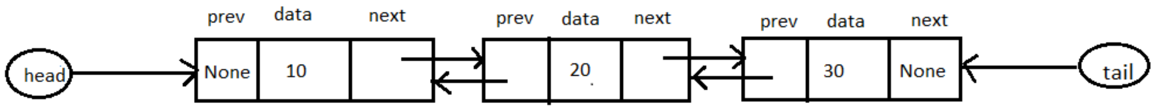
Representation



Doubly linked list

- `head` :- Store the reference of the first node. If the list is empty, then it stores `None`
- `tail` :- Store the reference of the last node. If the list is empty, then it stores `None`
- Each node have three fields:
    - `prev` :- store reference of the previous node
    - `data` :- Store actual value
    - `next` :- Store reference of the next node

Representation



Implementation of singly linked list in Python

- **Using one class- Recursively**

```
class Node:
    def __init__(self, v = None):
        self.value = v
        self.next = None
        return
    def isempty(self):
        if self.value == None:
            return(True)
        else:
            return(False)
    #recursive
    def append(self,v):
        if self.isempty():
            self.value = v
        elif self.next == None:
            self.next = Node(v)
        else:
            self.next.append(v)
        return
    # append, iterative
    def appendi(self,v):
        if self.isempty():
            self.value = v
            return
        temp = self
        while temp.next != None:
            temp = temp.next
        temp.next = Node(v)
        return
    def insert(self,v):
        if self.isempty():
            self.value = v
            return
        newnode = Node(v)
        # Exchange values in self and newnode
        (self.value, newnode.value) = (newnode.value, self.value)
        # Switch links
        (self.next, newnode.next) =(newnode, self.next)
        return
    # delete, recursive
    def delete(self,v):
        if self.isempty():
            return
        if self.value == v:
            self.value = None
```

```
            if self.next != None:
                self.value = self.next.value
                self.next = self.next.next
            return
        else:
            if self.next != None:
                self.next.delete(v)
                if self.next.value == None:
                    self.next = None
        return
    def display(self):
        if self.isempty()==True:
            print('None')
        else:
            temp = self
            while temp!=None:
                print(temp.value,end="  ")
                temp = temp.next
head = Node(10)
head.append(20)
head.append(30)
head.appendi(40)
head.appendi(50)
head.delete(30)
head.display()
```

- **Using two classes**

```
class Node:
    def __init__(self, data):
        self.data = data
        self.next = None
class LinkedList:
    def __init__(self):
        self.head = None
    def isempty(self):
        if self.head == None:
            return True
        else:
            return False
    def append(self,data):
        # If list is empty
        if self.isempty():
            self.head=Node(data)
        else:
            temp = self.head
            while temp.next != None:
                temp = temp.next
            temp.next = Node(data)
    def delete(self,v):
        # If list is empty
        if self.isempty()==True:
            return 'List is empty'
        # if list have only one element and equal to v
        elif self.head.next==None:
```

```
            if self.head.data==v:
                self.head = None
            else:
                return 'Not exist'
        else:
            temp = self.head
            temp1 = self.head
            while temp.next!= None and temp.data != v:
                temp1 = temp
                temp = temp.next
            if temp.data==v and temp==self.head:
                self.head = temp.next
            elif temp.data==v:
                temp1.next= temp.next
            else:
                return 'Not exist'
    def display(self):
        if self.isempty()==True:
            print('None')
        else:
            temp = self.head
            while temp!=None:
                print(temp.data,end="  ")
                temp = temp.next
L = LinkedList()
L.append(30)
L.append(40)
L.append(50)
L.delete(30)
L.display()
```

Advantage

- Insertion and deletion operations are easy
- many complex applications can be easily carried out with linked list concepts like tree, graph, etc.

Disadvantage

- More memory required to store data
- Random access is not possible

Application

- Implementation stack, queue, deque
- Representation of graph.
- Representation of sparse matrix
- Manipulation of the polynomial expression

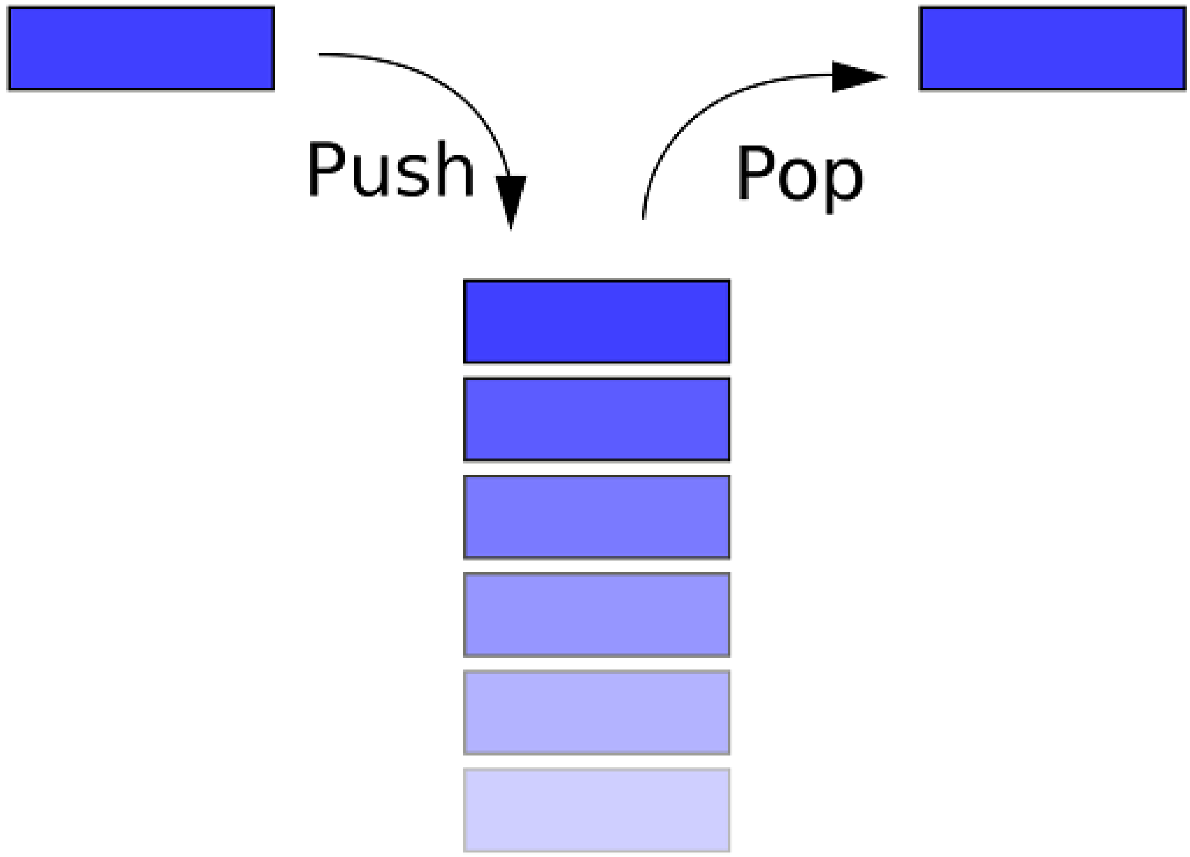
Visualization of Linked List

Source - https://visualgo.net/en/list

Stack

A Stack is a non-primitive linear data structure. It is an ordered list in which the addition of a new data item and deletion of an already existing data item can be done from only one end, known as `top` of the stack.

The last added element will be the first to be removed from the Stack. That is the reason why stack is also called Last In First Out (LIFO) type of data structure.



Basic operations on Stack

Push

The process of adding a new element to the top of the Stack is called the `Push` operation.

Pop

The process of deleting an existing element from the top of the Stack is called the `Pop` operation. It returns the deleted value.

Traverse/Display

The process of accessing or reading each element from top to bottom in Stack is called the `Traverse` operation.

Applications of Stack

- Reverse the string
- Evaluate Expression
- Undo/Redo Operation
- Backtracking
- Depth First Search(DFS) in Graph(Will be discussed in Week-4)

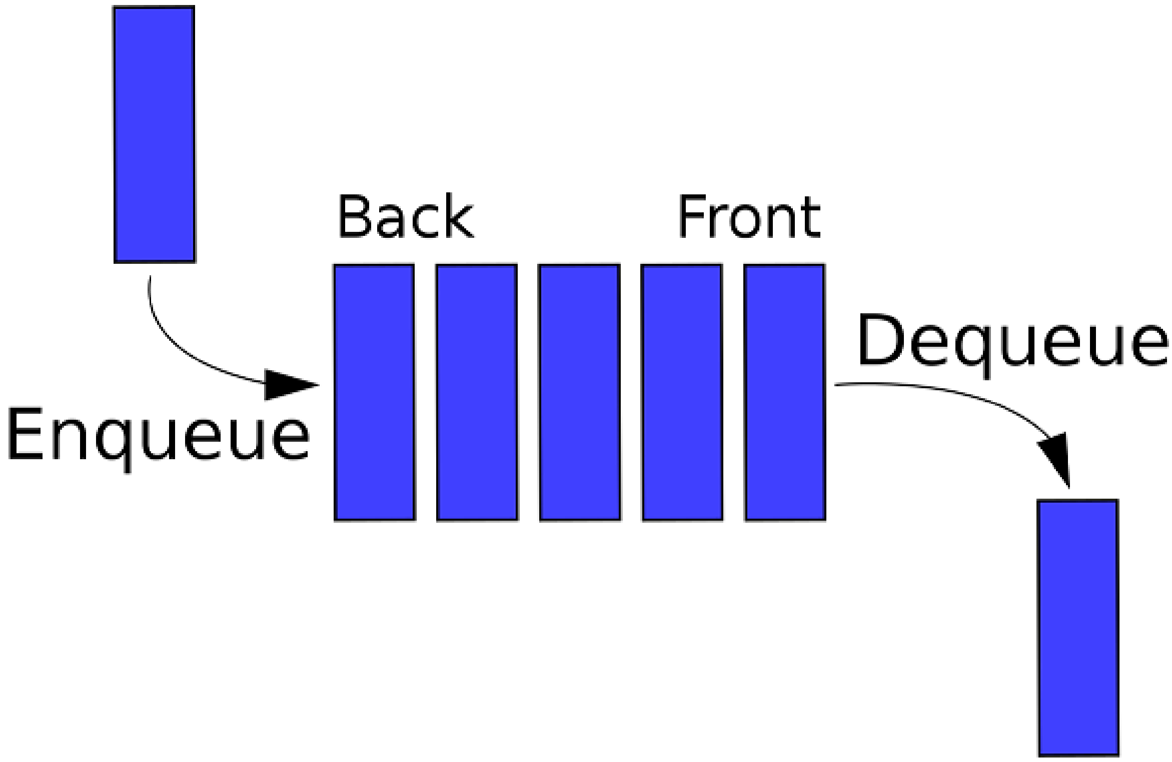
Implementation of Stack in Python

- Using a list
- Using a Linked list

Queue

The Queue is a non-primitive linear data structure. It is an ordered collection of elements in which new elements are added at one end called the `Back` end, and the existing element is deleted from the other end called the `Front` end.

A Queue is logically called a First In First Out (FIFO) type of data structure.



Basic operations on Queue

Enqueue

The process of adding a new element at the `Back` end of Queue is called the `Enqueue` operation.

Dequeue

The process of deleting an existing element from the `Front` of the Queue is called the `Dequeue` operation. It returns the deleted value.

Traverse/Display

The process of accessing or reading each element from `Front` to `Back` of the Queue is called the `Traverse` operation.

Applications of Queue

- Spooling in printers
- Job Scheduling in OS
- Waiting list application
- Breadth First Search(BFS) in Graph(Will be discussed in Week-4)

Implementation of the Queue in python

- Using a list
- Using a Linked list

Visualization of Stack and Queue

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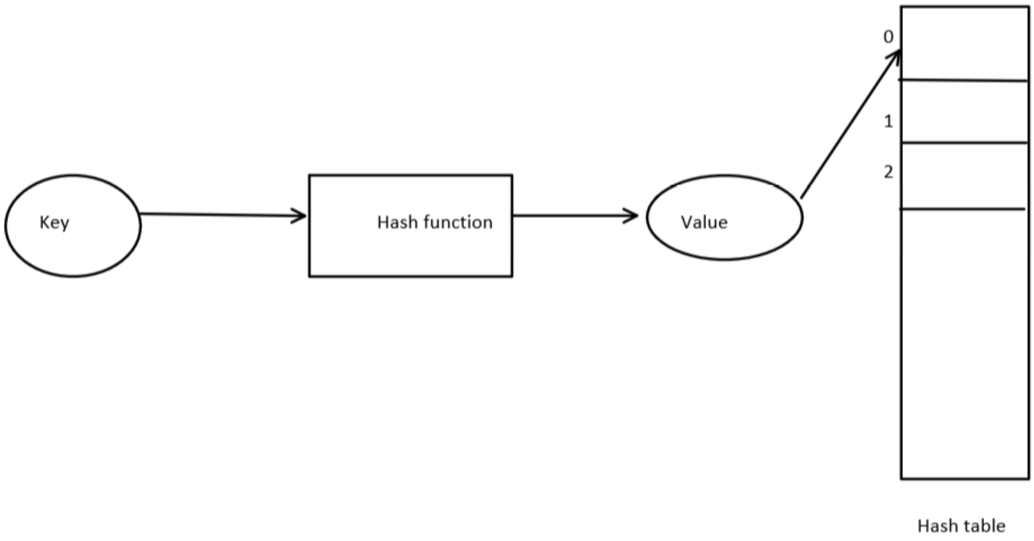
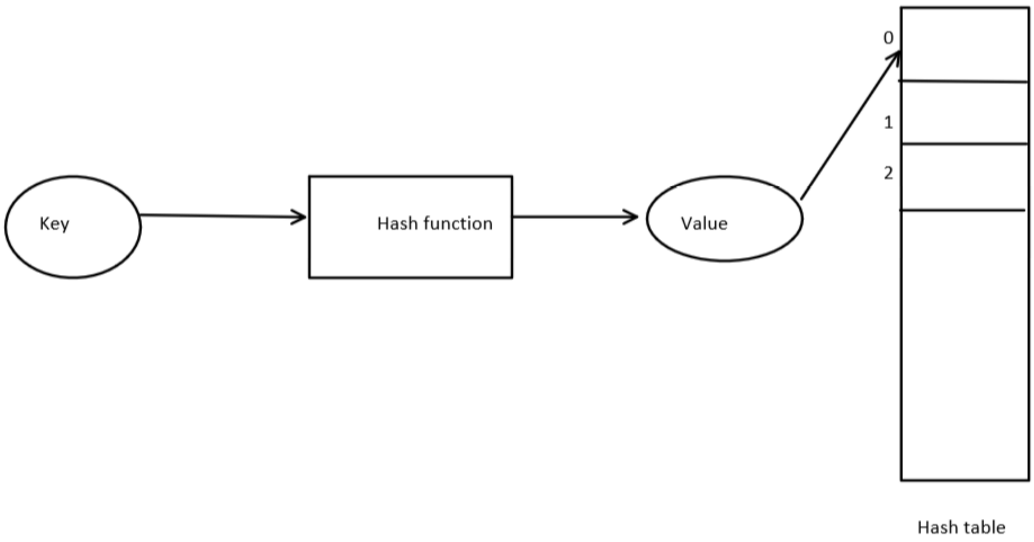
Hashing

Hashing is a technique or process of mapping keys, values into the hash table by using a hash function.

For storing element



For searching element



Collision:

The situation where a newly inserted key maps to an already occupied slot in the hash table is called **collision**.

Collision resolving technique

- **Open addressing(Close hashing)**
  - **Linear probing** is an open addressing scheme in computer programming for resolving hash collisions in hash tables. Linear probing operates by taking the original hash index and adding successive values linearly until a free slot is found.

    An example sequence of linear probing is:

    `h(k)+0, h(k)+1, h(k)+2, h(k)+3 .... h(k)+m-1`

    where `m` is a size of hash table, and `h(k)` is the hash function.

    Hash function

    Let `h(k) = k mod m` be a hash function that maps an element `k` to an integer in [0, $m-1$], where m is the size of the table. Let the `i` th probe position for a value `k` be given by the function `h'(k,i) = (h(k) + i) mod m`

The value of `i = 0, 1, . . ., m - 1`. So we start from `i = 0`, and increase this until we get a free block in hash table.

- **Quadratic probing** is an open addressing scheme in computer programming for resolving hash collisions in hash tables. Quadratic probing operates by taking the original hash index and adding successive values of an arbitrary quadratic polynomial until an open or empty slot is found.

  An example of a sequence using quadratic probing is:

  $$h, h+1, h+4, h+9 \ldots h+i^2$$

  Quadratic function

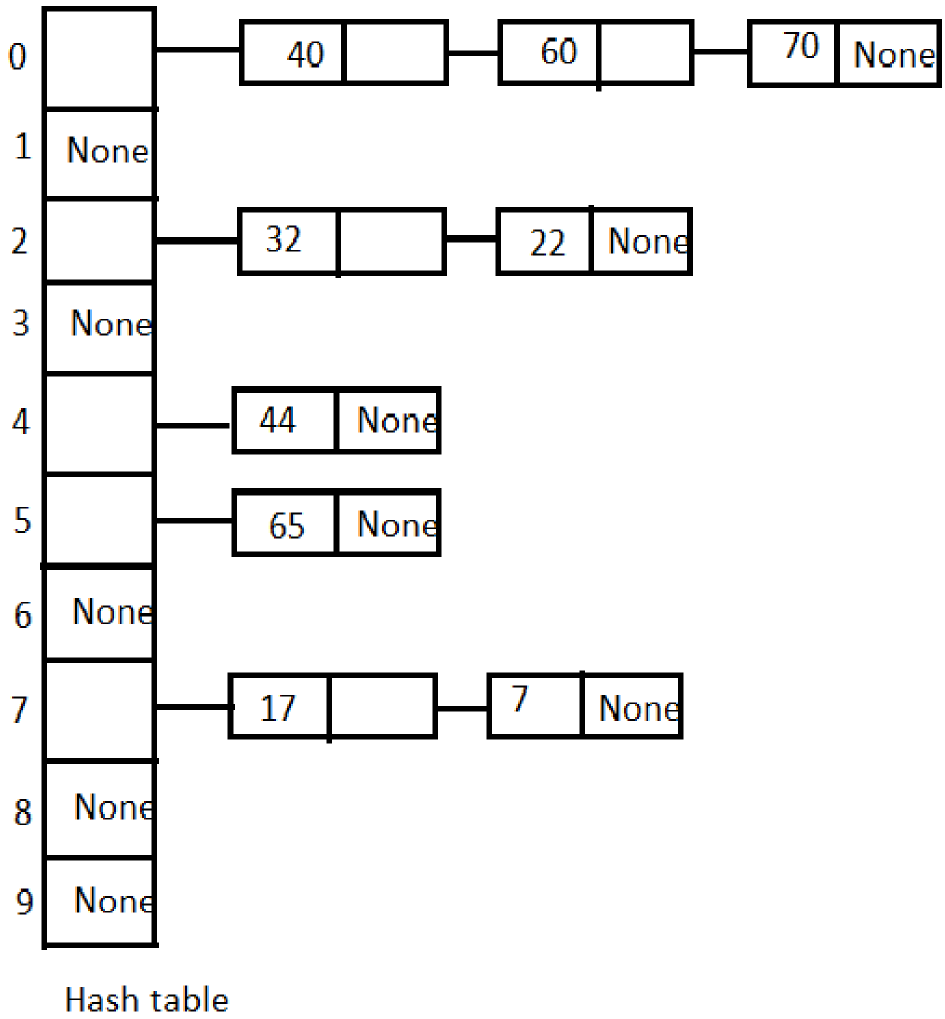
  Let `h(k) = k mod m` be a hash function that maps an element `k` to an integer in [0, *m*−1], where *m* is the size of the table. Let the i^{th} probe position for a value *k* be given by the function

  $$h(k,i) = (h(k) + c_1 i + c_2 i^2)\ mod\ m$$

  where `c1 and c2` are positive integers. The value of `i = 0, 1, . . ., m - 1`. So we start from `i = 0`, and increase this until we get one free slot in hash table.

- **Closed addressing (Open hashing)**
  - **Separate chaining using linked list**: Maintain the separate linked list for each possible generated index by the hash function.

    For example, if the hash function is `k mod 10` where k is the key and 10 is the size of the hash table.



Visualization of Hashing

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