Linked List

Introduction

- List of elements which are connected in sequence to each other by a set of pointers.
- Commonly used linear data structure.
- Each element is known as a node.
- A node consists of two parts
  - Data (value or values to be stored in a node).
  - Pointer (link to other nodes in a list).
- Types
  - Singly, Doubly, and Circular.

Contd…

- Advantages
  - Dynamic in nature, i.e. allocates memory when required.
  - Insertion and deletion operations can be executed easily.
  - Stacks and queues can be implemented easily.
  - Expands easily in real time.
  - Efficient memory utilization, i.e. no need to pre-allocate memory.
- Disadvantages
  - Wastage of memory as pointers require extra memory space.
  - No random access; everything sequential.
  - Reverse traversal is difficult if it’s singly.
  - Memory space restriction as new node can only be created if space is available in heap.

Operations

- Traversal (Searching, Displaying)
- Insertion
  - At the beginning.
  - At the end.
  - At a specific location.
- Deletion
  - At the beginning.
  - At the end.
  - At a specific location.

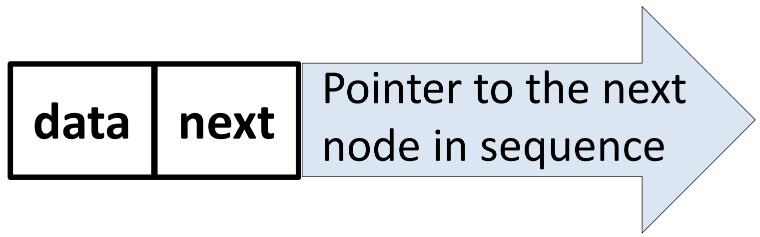
Singly Linked List

Introduction

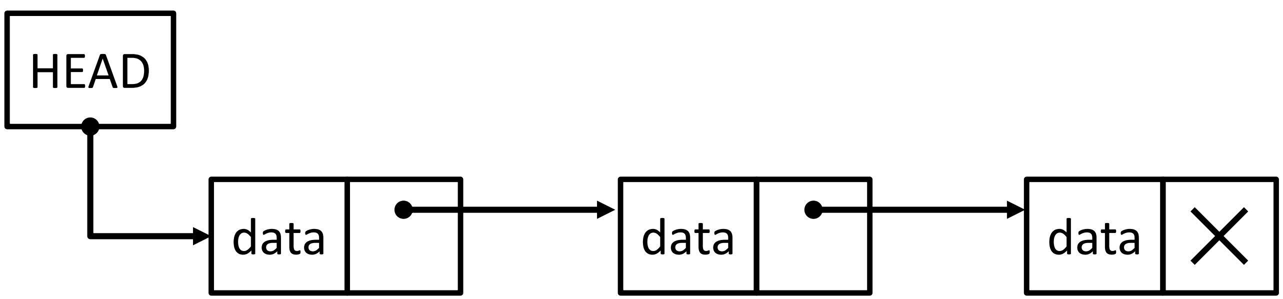
- The most basic type of linked list.
- Two successive nodes are linked together as each node contains address of the next node to be followed, i.e. successor.
- A node may has multiple data fields but only single link for the next node.
- Only forward sequential access is possible (or unidirectional).
- Address of the first node is always stored in a reference node known as **front** or **head**.
- The last node does not have any successor and has reference to **NULL**.

Contd…

- Pictorial representation of a node



- Pictorial representation of a singly linked list



Creation

```
struct node
{   int data;
    struct node *next; };
```

- Define node structure.
- Declare a NULL initialized head node pointer to create an empty list.

```
struct node *head = NULL;
```

- Dynamically allocate memory for a node and initialize all members of a node.

```
struct node *temp =
                    (struct node *) malloc (sizeof(struct node));
int num;
scanf("%d",&num);
temp -> data = num;
temp -> next = NULL;
```

Contd…

```
head = temp;
```

- Link the new node temp in the existing empty list.
- Again dynamically allocate memory for a node and initialize all members of a node.

```
*temp = (struct node *) malloc (sizeof(struct node));
scanf("%d",&num);
temp -> data = num;
temp -> next = NULL;
```

- Link the new node temp in the existing list at head.

```
temp -> next = head;
head = temp;
```

- This process is repeated for all the nodes. A node can be inserted anywhere in the list.

Insertion at beginning of the list

- **Algorithm** insertBeg(head, num)
- **Input**: Pointer to the first node (**head**) and a new value to insert (**num**).
- **Output**: Node with value **num** gets inserted at the first position.

1. Create a node pointer (**temp**).
2. **temp**[**data**] = **num**.
3. **temp**[**next**] = **head**.
4. **head** = **temp**.

Display elements in the list

- **Algorithm** display(head)
- **Input**: Pointer to the first node (**head**).
- **Output**: Display all the elements present in the list.

1. If (**head == NULL**)
2. Print [**List is Empty**].
3. Return.
4. Initialize a node pointer (**temp**) with **head**.
5. while (**temp** is not **NULL**)
6. Print [**temp**[**data**]].
7. **temp** = **temp**[**next**].

Search an element in the list

- **Algorithm** search(head, num)
- **Input**: Pointer to the first node (**head**) and a value to search (**num**).
- **Output**: Appropriate message will be displayed.

1. If (**head == NULL**)
2. Print [**List is Empty**].
3. Return.
4. Initialize a node pointer (**temp**) with **head**.
5. while (**temp** is not **NULL** AND **temp**[**data**] is not equal to **value**)
6. **temp** = **temp**[**next**]
7. if (**temp** is **NULL**)
8. Print [**Element not found**].
9. Else
10. Print [**Element found**].

Insertion at end of the list

- **Algorithm** insertEnd(head, num)
- **Input**: Pointer to the first node (**head**) and a new value to insert (**num**).
- **Output**: Node with value **num** gets inserted at the last position.

1. Create a node pointer (**temp**).
2. **temp**[**data**] = **num**
3. **temp**[**next**] = **NULL**
4. If (**head** == **NULL**)
5.   **head** = **temp**
6. Else
7.   Initialize a node pointer (**temp1**) with **head**.
8.   while (**temp1**[**next**] is not equal to **NULL**)
9.   **temp1** = **temp1**[**next**]
10.   **temp1**[**next**] = **temp**

Insertion after a specific value in the list

- **Algorithm** insert(head, num, value)
- **Input**: Pointer to the first node (**head**) and a new value to insert (**num**) after an existing **value**.
- **Output**: Node with value **num** gets inserted after node with **value**.

1. Create a node pointer (**temp**).
2. **temp**[**data**] = **num**
3. **temp**[**next**] = **NULL**
4. Initialize a node pointer (**temp1**) with **head**.
5. while (**temp1 != NULL** AND **temp1**[**data**] != **value**)
6. **temp1** = **temp1**[**next**]

Contd…

7. if (**temp1** == **NULL**)
8. print [**Node is not present in the list**]
9. else
10. **temp**[**next**] = **temp1**[**next**]
11. **temp1**[**next**] = **temp**
12. end if (line 7).

Delete from beginning of the list

- **Algorithm** deleteBeg(head)
- **Input**: Pointer to the first node (**head**).
- **Output**: The first node gets deleted.

1. If (**head == NULL**)
2. Print [**List is Empty**].
3. Else
4. initialize a node pointer (**temp**) with **head**.
5. **head = head**[**next**]
6. Release the memory location pointed by **temp**.
7. end if

Delete from end of the list

- **Algorithm** deleteEnd(head)
- **Input**: Pointer to the first node (**head**).
- **Output**: The last node gets deleted.

1. If (**head** == **NULL**)
2.   Print [**List is Empty**].
3. Else
4.   initialize a node pointer (**temp**) with **head**.
5.   while (**temp**[**next**] is not **NULL**)
6.   initialize a node pointer (**pre**) with **temp**.
7.   **temp** = **temp[next]**
8.   if (**temp** == **head**)
9.   **head** = **NULL**
10.   else
11.   **pre**[**next**] = **NULL**
12.   Release the memory location pointed by **temp**.
13. end if

Delete a specific node from the list

- **Algorithm** deleteSpecific(head,num)
- **Input**: Pointer to the first node (**head**) and a value **num** to be deleted.
- **Output**: The node with value **num** gets deleted.

1. If (**head == NULL**)
2.   Print [**List is Empty**].
3. Else
4.   initialize a node pointer (**temp**) with **head**.
5.   while (**temp** is not **NULL** AND **temp**[**data**] is not equal to **value**)
6.   initialize a node pointer (**pre**) with **temp**.
7.   **temp = temp[next]**
8.   if (**temp** is **NULL**)
9.   Print [**Element not found**].
10.   Return.

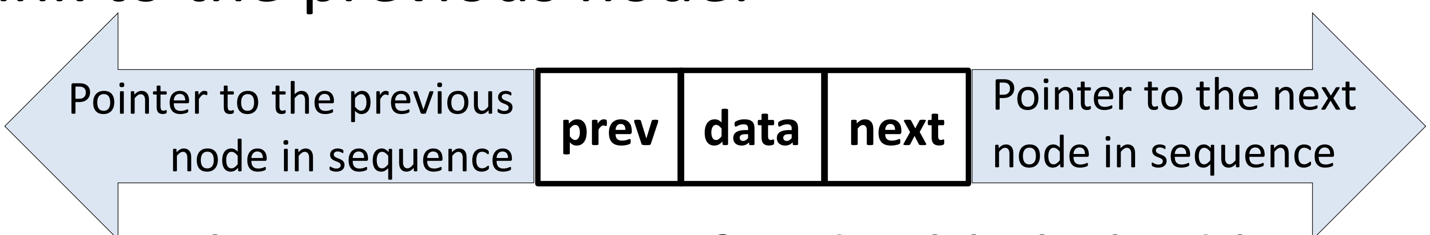
Contd…

12. else if (**temp == head**)
13. **head** = **head[next]**
14. else if (**temp**[**next**] **== NULL**)
15. **pre**[**next**] = **NULL**
16. else
17. **pre**[**next**] = **temp**[**next**]
18. Release the memory location pointed by **temp**.
19. end if (line 8).
20. end if (line 1).

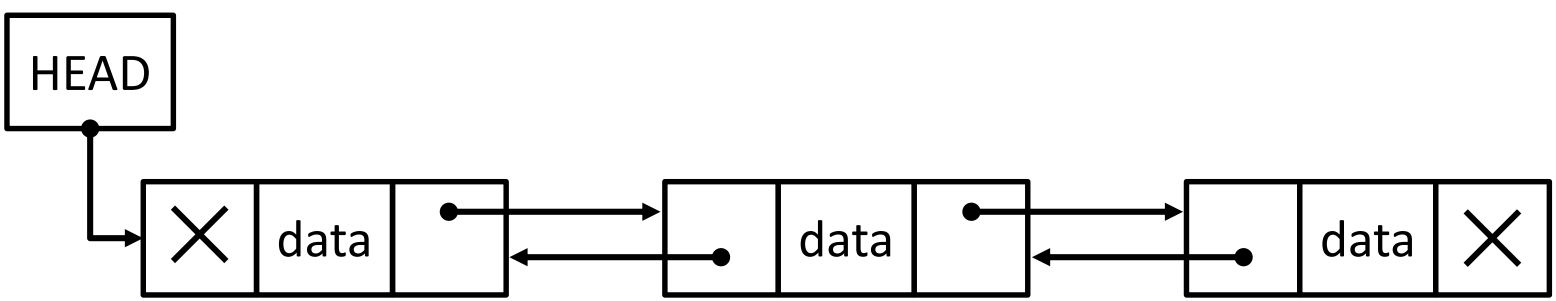
Doubly Linked List

Introduction

- Sequence of elements in which every element has links to its previous element and next element in the sequence.
- Each node contains three fields: data, link to the next node, and link to the previous node.



- The pictorial representation for doubly linked list is as shown below:



Contd…

- Advantages:
  - Can be traversed in either direction.
  - Some operations, such as deletion and insertion before a node, become easier.

- Disadvantages:
  - Requires more space.
  - List manipulations are slower.
  - Greater chances of having bugs.

Creation

```
struct node
{   int data;
    struct node *next, *prev; };
```

- Define node structure.
- Declare a NULL initialized head node pointer to create an empty list.

```
struct node *head = NULL;
```

- Dynamically allocate memory for a node and initialize all members of a node.

```
struct node *temp =
                 (struct node *) malloc (sizeof(struct node));
int num;
scanf("%d",&num);
temp -> data = num;
temp -> prev = temp -> next = NULL;
```

Contd…

```
head = temp;
```

- Link the new node temp in the existing empty list.
- Again dynamically allocate memory for a node and initialize all members of a node.

```
*temp = (struct node *) malloc (sizeof(struct node));
scanf("%d",&num);
temp -> data = num;
temp -> prev = temp -> next = NULL;
```

- Link the new node temp in the existing list at head.

```
temp -> next = head; head -> prev = temp;
head = temp;
```

- This process is repeated for all the nodes. A node can be inserted anywhere in the list.

Search an element in the list

- **Algorithm** search(head, num)
- **Input**: Pointer to the first node (**head**) and a value to search (**num**).
- **Output**: Appropriate message will be displayed.

1. If (**head == NULL**)
2. Print [**List is Empty**].
3. Return.
4. Initialize a node pointer (**temp**) with **head**.
5. while (**temp** is not **NULL** AND **temp**[**data**] is not equal to **value**)
6. **temp** = **temp**[**next**]
7. if (**temp** is **NULL**)
8. Print [**Element not found**].
9. Else
10. Print [**Element found**].

Display elements in the list

- **Algorithm** display(head)
- **Input**: Pointer to the first node (**head**).
- **Output**: Display all the elements present in the list.

1. If (**head == NULL**)
2. Print [**List is Empty**].
3. Return.
4. Initialize a node pointer (**temp**) with **head**.
5. while (**temp** is not **NULL**)
6. Print [**temp**[**data**]].
7. **temp** = **temp**[**next**].

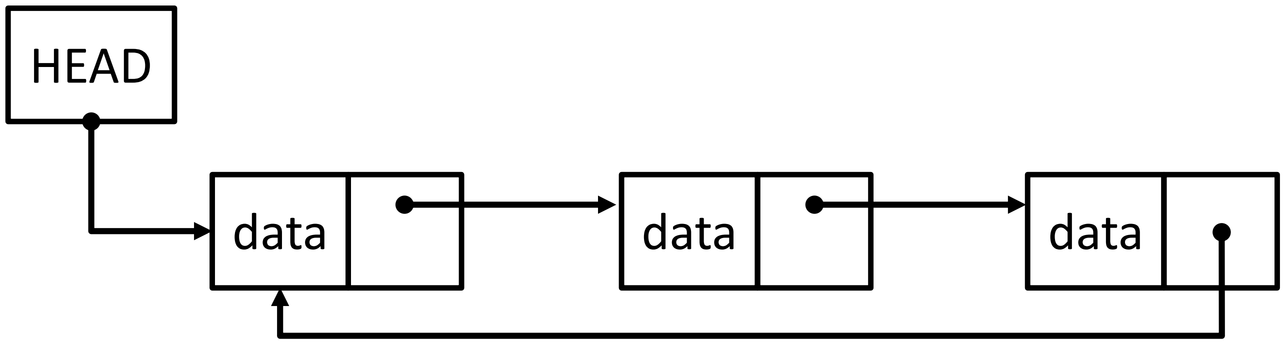
Circular Linked List

Introduction

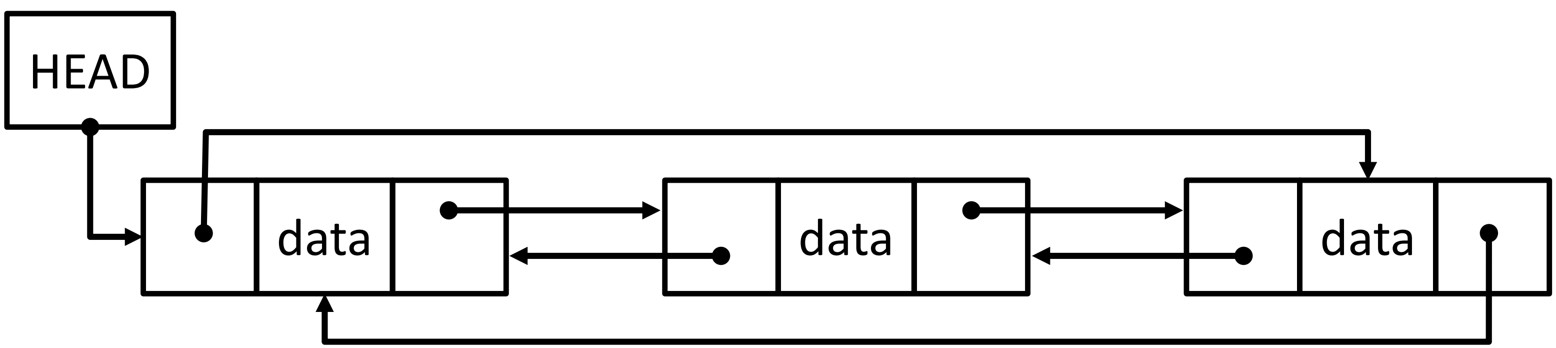
- The first element points to the last element and the last element points to the first element.
- There is no NULL node.
- While traversal, get back to a node from where you have started.
- Pointer to any node can serve as a handle to the complete list.
- Both singly and doubly linked lists can be circular.

Contd…

- Singly linked list as circular



- Doubly linked list as circular



Creation

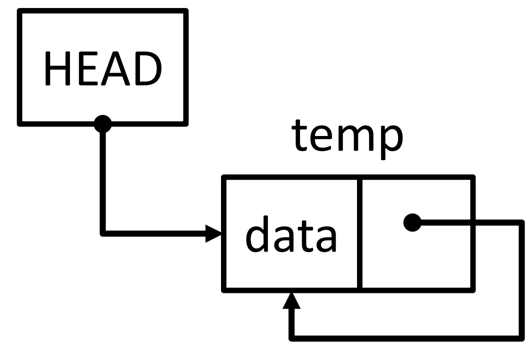
- Define node structure.
- Declare a NULL initialized head node pointer to create an empty list.
- Dynamically allocate memory for a node and initialize all members of a node.
- Link the new node temp in the existing empty list.
- Again dynamically allocate memory for a node and initialize all members of a node.
- Link the new node temp in the existing list at head.
- This process is repeated for all the nodes. A node can be inserted anywhere in the list.

Contd…

- Link the new node temp in the existing empty list.

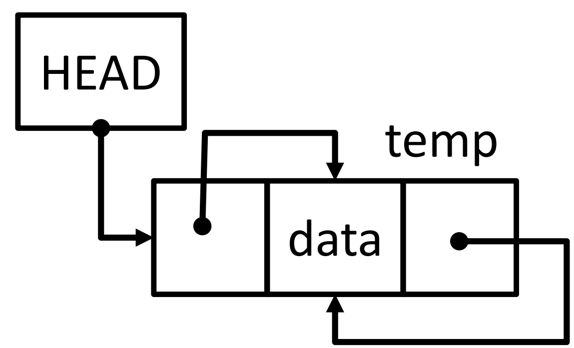
- Singly

```
head = temp;
temp -> next = head;
```



- Doubly

```
head = temp;
temp -> prev = head;
temp -> next = head;
```



Contd…

- Link the new node temp in the existing list at head.

- Singly: temp1 is a node pointer pointing to the last node in a linked list.

```
temp -> next = head;
temp1 -> next = temp;
head = temp;
```

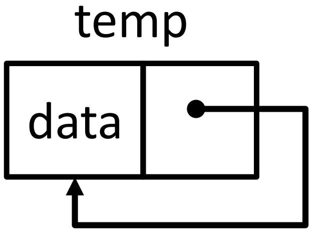
- Doubly

```
temp -> next = head;
temp -> prev = head -> prev;
head -> prev = temp;
temp -> prev -> next = temp;
head = temp;
```

Insertion at beginning of the list (singly)

- **Algorithm** insertBeg(head, num)
- **Input**: Pointer to the first node (**head**) and a new value to insert (**num**).
- **Output**: Node with value **num** gets inserted at the first position.

1. Create a node pointer (**temp**).
2. **temp**[**data**] = **num**.
3. if (**head** == **NULL**)
4. **temp**[**next**] = **temp**.



Contd…

5. else
6.   **temp**[**next**] = **head**.
7.   Initialize a node pointer (**temp1**) with **head**.
8.   while (**temp1**[**next**] is not equal to **head**)
9.   **temp1** = **temp1**[**next**]
10.   **temp1**[**next**] = **temp**.
11. end if (line 3).
12. **head** = **temp**.

Search an element in the list

- **Algorithm** search(head, num)
- **Input**: Pointer to the first node (**head**) and a value to search (**num**).
- **Output**: Appropriate message will be displayed.

1. If (**head == NULL**)
2.   Print [**List is Empty**].
3.   Return.
4. Initialize a node pointer (**temp**) with **head**.
5. while (**temp**[**next**] != **head** AND **temp**[**data**] != **value**)
6.   **temp** = **temp**[**next**]
7. if (**temp**[**data**] == **value**)
8.   Print [**Element found**].
9. Else
10.   Print [**Element not found**].

Display elements in the list

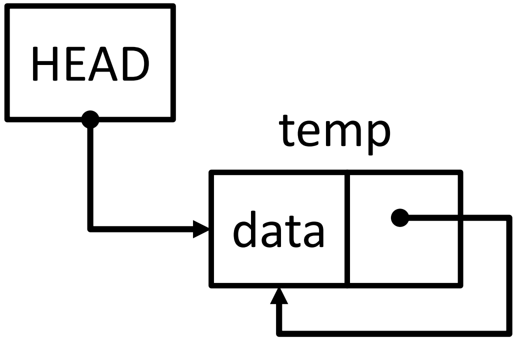
- **Algorithm** display(head)
- **Input**: Pointer to the first node (**head**).
- **Output**: Display all the elements present in the list.

1. If (**head** == **NULL**)
2. Print [**List is Empty**].
3. Return.
4. Initialize a node pointer (**temp**) with **head**.
5. while (**temp**[**next**] is not **head**)
6. Print [**temp**[**data**]].
7. **temp** = **temp**[**next**].
8. Print [**temp**[**data**]].

Insertion at end of the list (singly)

- **Algorithm** insertEnd(head, num)
- **Input**: Pointer to the first node (**head**) and a new value to insert (**num**).
- **Output**: Node with value **num** gets inserted at the last position.

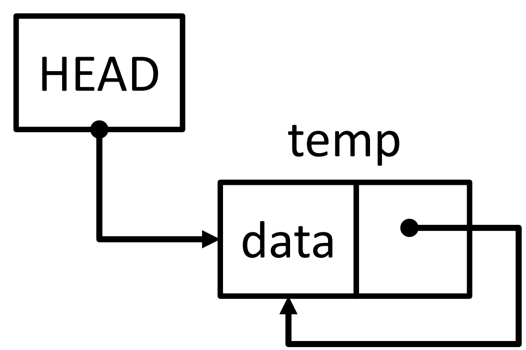
1. Create a node pointer (**temp**).
2. **temp**[**data**] = **num**
3. If (**head == NULL**)
4. **temp**[**next**] = **temp**
5. **head** = **temp**
6. Else
7. Initialize a node pointer (**temp1**) with **head**.
8. while (**temp1**[**next**] is not equal to **head**)
9. **temp1** = **temp1**[**next**]
10. **temp1**[**next**] = **temp**
11. **temp**[**next**] = **head**



Insertion after a specific value in the list (singly)

- **Algorithm** insert(head, num, value)
- **Input**: Pointer to the first node (**head**) and a new value to insert (**num**) after an existing **value**.
- **Output**: Node with value **num** gets inserted after node with **value**.

1. Create a node pointer (**temp**).
2. **temp**[**data**] = **num**
3. If (**head** == **NULL**)
4. **temp**[**next**] = **temp**
5. **head** = **temp**



Contd…

6. else
7.   Initialize a node pointer (**temp1**) with **head**.
8.   while (**temp1**[**next**] != **head** AND **temp1**[**data**] != **value**)
9.   **temp1** = **temp1**[**next**]
10.   if (**temp1**[**data**] != **value**)
11.   print [**Node is not present in the list**]
12.   else
13.   **temp**[**next**] = **temp1**[**next**]
14.   **temp1**[**next**] = **temp**
15.   end if (line 10).
16. End if (line 3).

Delete from beginning of the list (singly)

- **Algorithm** deleteBeg(head)
- **Input**: Pointer to the first node (**head**).
- **Output**: The first node gets deleted.

1. If (**head** == **NULL**)
2. Print [**List is Empty**].
3. Else
4. initialize node pointers (**temp** and **temp1**) with **head**.
5. while (**temp1**[**next**] is not equal to **head**)
6. **temp1** = **temp1**[**next**]
7. if (**temp1** == **head**)
8. **head** == **NULL**
9. else
10. **temp1**[**next**] = **head**[**next**].
11. **head = head**[**next**]
12. Release the memory location pointed by **temp**.

Delete from end of the list (singly)

- **Algorithm** deleteEnd(head)
- **Input**: Pointer to the first node (**head**).
- **Output**: The last node gets deleted.

1. If (**head** == **NULL**)
2. Print [**List is Empty**].
3. Else
4. initialize a node pointer (**temp**) with **head**.
5. while (**temp**[**next**] is not **head**)
6. initialize a node pointer (**pre**) with **temp**.
7. **temp** = **temp[next]**
8. if (**temp** == **head**)
9. **head** = **NULL**
10. else
11. **pre**[**next**] = **head**
12. Release the memory location pointed by **temp**.

Delete a specific node from the list (singly)

- **Algorithm** deleteSpecific(head,num)
- **Input**: Pointer to the first node (**head**) and a value **num** to be deleted.
- **Output**: The node with value **num** gets deleted.

1. If (**head == NULL**)
2. Print [**List is Empty**].
3. Else
4. initialize a node pointer (**temp**) with **head**.
5. while (**temp**[**next**] != **head** AND **temp**[**data**] != **value**)
6. initialize a node pointer (**pre**) with **temp**.
7. **temp = temp[next]**
8. if (**temp**[**data**] != **value**)
9. Print [**Element not found**].
10. Return.

Contd…

11. else if (**temp == head**)
12. deleteBeg(**head**)
13. else if (**temp**[**next**] **== head**)
14. deleteEnd(**head**)
15. else
16. **pre**[**next**] = **temp**[**next**]
17. Release the memory location pointed by **temp**.
18. end if (line 8).
19. end if (line 1).

Thankyou