COMP1038.PGA

Session 15: Singly Linked List

Overview

- Linked list
  - Introduction
  - Creation
  - Insertion
  - Deletion
  - Printing
  - Searching
  - Application

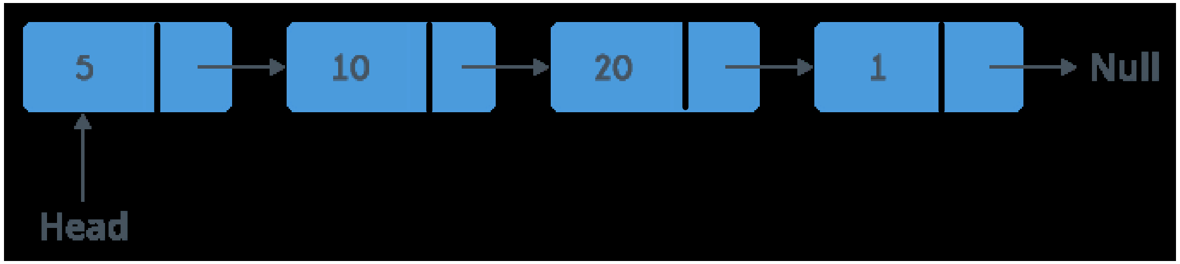
Introduction

- Lists are linear data structures which store elements of the list one after another.
- Unlike arrays, we can add/remove elements without having to re-create the entire data structure.
- Insert/remove elements from anywhere in the list.
- Access elements anywhere in the list, but slower than arrays.

Introduction cont…

- Linked list is a list of elements that are connected to each other by pointers.

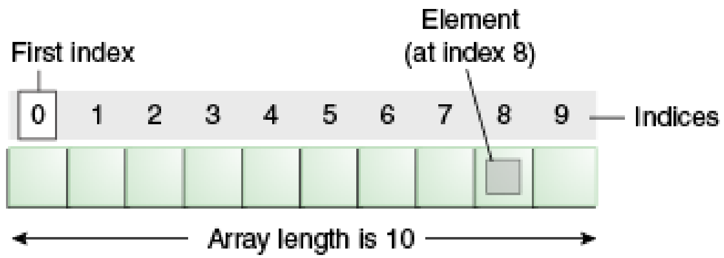
```
struct Node
{
  int data;
  struct Node *next;
}
```



Comparison with Array

- Collection of items stored at continuous memory location.

```c
#include <stdio.h>

int main()
{
        int arr[3] = {1, 2, 3};

        int i = 0;
        for(i = 0; i < 3; i++)
        {
                printf("#%d: %d\n", i, arr[i]);
        }

        // random access
        printf("\n\nRandom access #%d: %d\n", 2, arr[2]);

        return 0;
}
```



Source: https://docs.oracle.com/javase/tutorial/java/nutsandbolts/arrays.html

```
[z2017233@CSLinux Desktop]$ gcc c_test.c -o c_test
[z2017233@CSLinux Desktop]$ ./c_test
#0: 1
#1: 2
#2: 3


Random access #2: 3
```

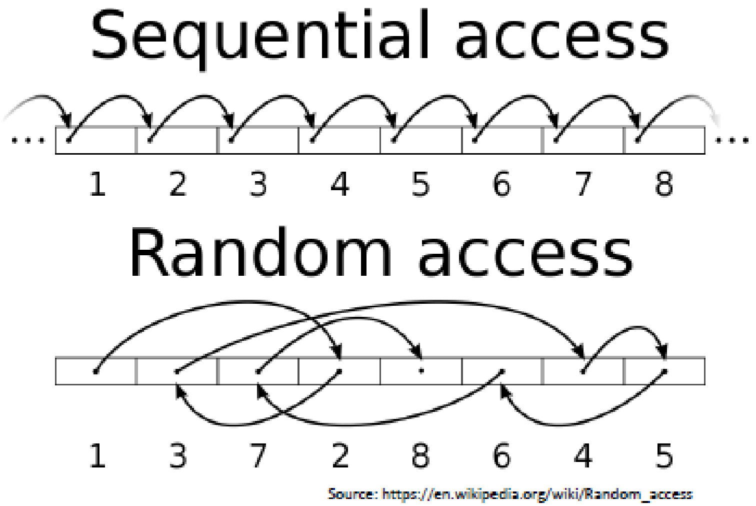
Comparison with Array cont...

- Linked list:
  - Can be of any size as long as memory permits
  - Insertion and deletion of data is easier
- Array:
  - Size is fixed i.e. if array is created, cannot change size again during execution of program.
  - Insertion and deletion of data is difficult

Comparison with Array cont...

- Linked list: sequential access

```c
// This function prints contents of linked list starting from head
void printList(struct Node *node)
{
  while (node != NULL)
  {
     printf(" %d ", node->data);
     node = node->next;
  }
}
```

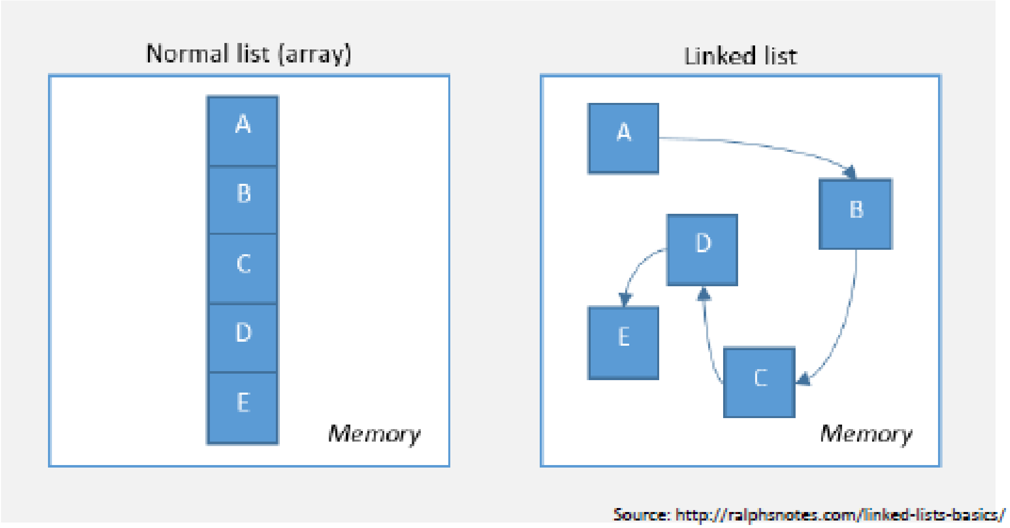


- Array: random access

```c
// random access
printf("\n\nRandom access #%d: %d\n", 2, arr[2]);
```

Comparison with Array cont…

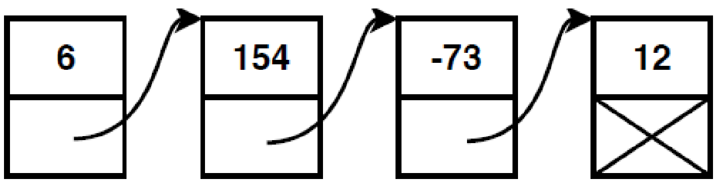
- Memory allocation:



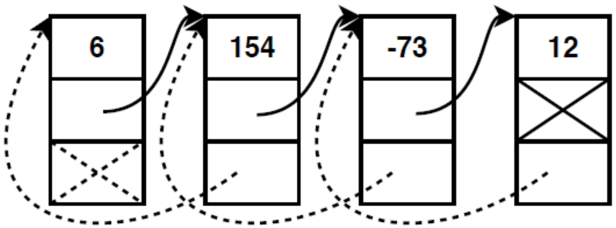
Source: http://ralphsnotes.com/linked-lists-basics/

Types

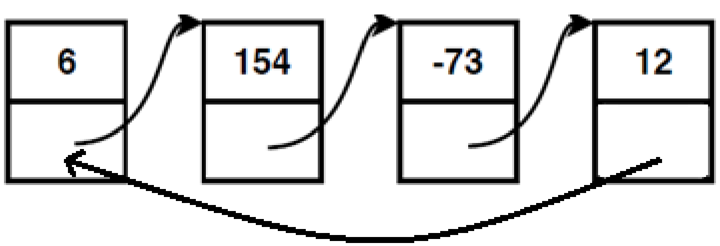
- **Singly Linked list**
  - A pointer to the next element of the list.
  - Indicate end of list with NULL in the last pointer.
  - Can only navigate the list in one direction.
  - Accessing previous element requires traversing from the start of the list again.



- **Doubly Linked list**
  - Pointer to next element as with singly-linked list.
  - Pointer to previous element as well.
  - Can access previous element just by using previous pointer.
  - More efficient navigation but more complex algorithms and larger storage requirements



- **Circular Linked list**
  - A pointer to the next element of the list.
  - End node of the list points to the first node of the list
  - Can only navigate the list in one direction.



Creation

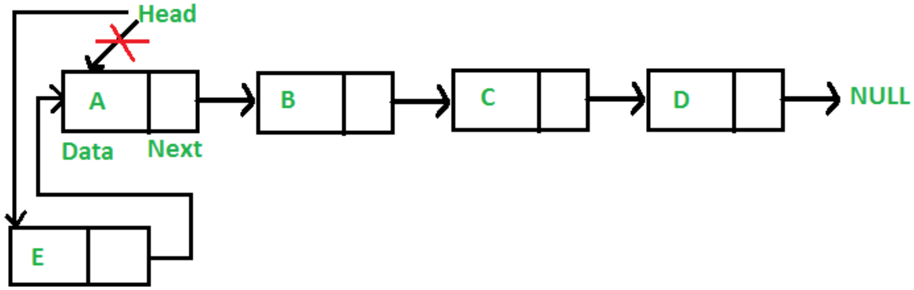
```
struct Node
{
    int data;
    struct Node *next;
}
```

```
int main()
{
    struct Node *list =
            malloc(sizeof(struct Node));
    ...
}
```

Insertion

- **Insertion at the beginning**

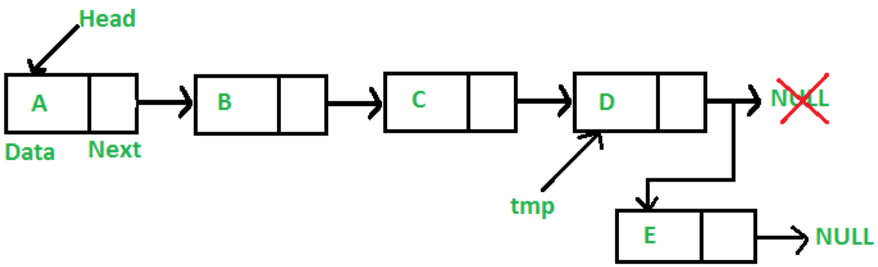
```
/* Given a reference (pointer to pointer) to the head of a list
   and an int,  inserts a new node on the front of the list. */
void insertBegining(struct Node** head_ref, int new_data)
{
    /* 1. allocate node */
    struct Node* new_node = (struct Node*) malloc(sizeof(struct
Node));

    /* 2. put in the data  */
    new_node->data  = new_data;

    /* 3. Make next of new node as head */
    new_node->next = (*head_ref);

    /* 4. move the head to point to the new node */
    (*head_ref)    = new_node;
}
```



Insertion cont…

- **Insertion at the end**

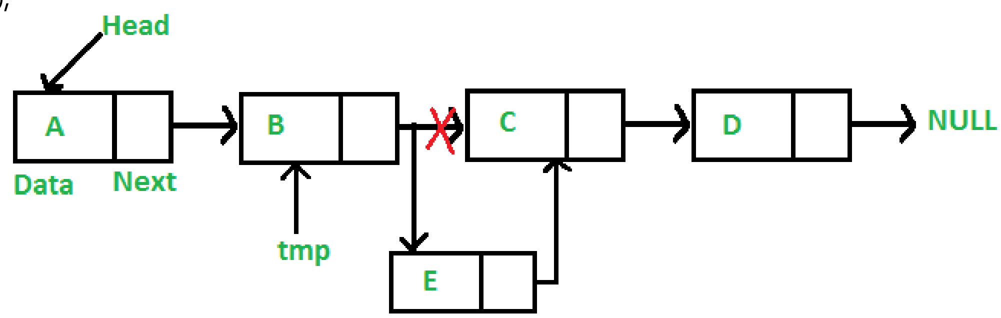
```
/* Given a reference (pointer to pointer) to the head of a list and an int, appends a new node at the end */
void append(struct Node** head_ref, int new_data)
{
    /* 1. allocate node */
    struct Node* new_node = (struct Node*) malloc(sizeof(struct Node));
    struct Node *tmp = *head_ref; /* used in step 5*/

    /* 2. put in the data */
    new_node->data = new_data;

    /* 3. This new node is going to be the last node, so make next of it as NULL*/
    new_node->next = NULL;

    /* 4. If the Linked List is empty, then make the new node as head */
    if (*head_ref == NULL)
    {  *head_ref = new_node;
       return; }

    /* 5. Else traverse till the last node */
    while (tmp->next != NULL)
        tmp = tmp->next;

    /* 6. Change the next of last node */
    tmp->next = new_node;
    return;
}
```



Insertion cont...

- **Add a node after a given key:**

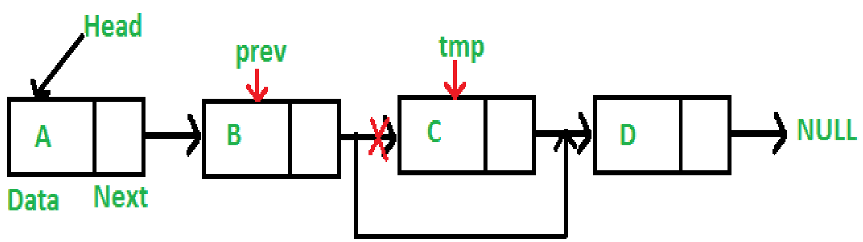
```
/* Given a key, insert a new node after the key */
void insertAfter(struct Node **head_ref, int new_data, int insert_after)
{
    node *tmp = *head_ref;

    /*1. allocate node */
    struct Node *new_node = (struct Node *) malloc(sizeof(node));

    /*2.  put in the data */
    new_node->data = new_data;

    /*3. Search for the key to be inserted after */
     while (tmp != NULL && tmp->data != insert_after)
       tmp = tmp->next;

    /*4. If key was not present in linked list */
    if (tmp == NULL) return;

    /*5. Make next of new node as next of prev_node */
    new_node->next = tmp->next;

    /*6. move the next of prev_node as new_node */
    tmp->next = new_node;
}
```



Deletion

- **Delete a node with given key**

1) Find previous node of the node to be deleted.
2) Change the next of previous node.
3) Free memory for the node to be deleted.




```c
/* Given a reference (pointer to pointer) to the head of a list
  and a key, deletes the first occurrence of key in linked list */
void deleteKey(struct Node **head_ref, int key)
{
   /*1. Store head node */
   struct Node* tmp = *head_ref, *prev;

   /*2 If head node itself holds the key to be deleted */
   if (tmp != NULL && tmp->data == key)
   {
      *head_ref = tmp->next;   // Changed head
      free(tmp);               // free old head
      return;
   }

   /*3 Search for the key to be deleted, keep track of the
   previous node as we need to change 'prev->next' */
   while (tmp != NULL && tmp->data != key)
   {
      prev = tmp;
      tmp = tmp->next;
   }

   /*4 If key was not present in linked list */
   if (tmp == NULL) return;

   /*5 Unlink the node from linked list */
   prev->next = tmp->next;

   free(tmp);  // Free memory
}
```

Deletion cont…

- **Delete a Linked List node at a given position**

```
/* Given a reference (pointer to pointer) to the head of a list
  and a position, deletes the node at the given position */
void deletePos(struct Node **head_ref, int position)
{
  /*1 If linked list is empty */
  if (*head_ref == NULL)
    return;

  /*2 Store head node */
  struct Node* temp = *head_ref;

  /*3 If head needs to be removed */
  if (position == 0)
  {
    *head_ref = temp->next;   // Change head
    free(temp);               // free old head
    return;
  }

  /*4 Find previous node of the node to be deleted */
  for (int i=0; temp!=NULL && i<position-1; i++)
    temp = temp->next;

  /*5 If position is more than number of ndoes */
  if (temp == NULL || temp->next == NULL)
    return;

  /*6 Node temp->next is the node to be deleted
   Store pointer to the next of node to be deleted */
  struct Node *next = temp->next->next;

  /*7 Unlink the node from linked list
  free(temp->next);  // Free memory

  /*8 Unlink the deleted node from list */
  temp->next = next;
}
```

Printing

```
/* This function prints contents of linked list starting from the given node */
void printList(struct Node **head_ref)
{
    node *tmp = *head_ref;
        if(tmp==NULL)
        {
           printf("empty");
           return;
        }
        while (tmp != NULL)
        {
           printf("%d ",tmp->data);
           tmp = tmp->next;
        }
}
```

Searching an item

1) Initialize a node pointer, current = head.
2) Do following while current is not NULL
   a) current->key is equal to the key being searched return true.
   b) current = current->next
3) Return false

```
/* Checks whether the value x is present in linked list */
int search(struct Node** head_ref, int key)
{
   struct Node* tmp = *head_ref;  // Initialize current
   while (tmp != NULL)
   {
      if (tmp ->key == key)
         return 1;
       tmp = tmp ->next;
   }
   return 0;
}
```

Linked list: application

- **Applications of linked list in computer science:**
  - Implementation of stacks and queues
  - Implementation of graphs : Adjacency list representation of graphs is most popular which is uses linked list to store adjacent vertices.
  - Dynamic memory allocation : We use linked list of free blocks.
  - Maintaining directory of names
  - Performing arithmetic operations on long integers
  - Manipulation of polynomials by storing constants in the node of linked list representing sparse matrices

- **Applications of linked list in real world:**
  - Image viewer – Previous and next images are linked, hence can be accessed by next and previous button.
  - Previous and next page in web browser – We can access previous and next url searched in web browser by pressing back and next button since, they are linked as linked list.
  - Music Player – Songs in music player are linked to previous and next song. you can play songs either from starting or ending of the list.

The End