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2nd class

Data Structures and Algorithms

هياكل البيانات والخوارزميات

استاذ الماده: م.م. رغيد داؤود سالم

Data structure:

A collection of data elements whose organization is characterized by accessing operation that are used to store and retrieve the individual are elements.

Algorithm:- is s finite set of instructions which, if followed, accomplish a particular task. In our course, it is not enough to specify the form of data structure, but we must give also the algorithm of operation to access these data structures. Any algorithm must satisfy the following criteria.

1- Input.
2- Output.
3- Definiteness.
4- Finiteness.
5- Effectiveness.

How to choose the suitable data structure

For each set of, data there are different methods to organize these data in a particular data structure. To choose the suitable data structure, we must use the following criteria.

1- Data size and the required memory.
2- The dynamic nature of the data.
3- The required time to obtain any data element from the data structure.
4- Te programming approach and the algorithm that will be used to manipulate these.

Built – In Data Structures

Programming language usually provide some data structures that are built into the language, for instance, C x C^{++} provide structures and arrays of various dimensions.

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Arrays in C

Array is the first data structure that is built in the C language so it can be considered as a data type in the language. The simplest form of array a one-dimensional array that may be defined abstractly as a finite ordered set of homogenous elements.

By "finite" we mean that these is a specific number of elements in the array. This number may be large or small, but it must exit.

By "ordered" we mean that the elements of the array are arranged so that there is a zeroth, first, second, third, and so forth.

By "homogeneous" we mean that all the elements in the array must be of the same type. For example an array may contain all integers or all characters but may not contain both.

Necessary to develop a method of ordering its elements in a linear fashion and transforming a two.

Dimensional reference to the linear representation. One method of representing a two-dimensional array in memory is the raw-major representation. Under this representation the first row of the array occupies the first set of memory locations reserved for the array, the second row occupies in next set, and so forth.

Let us suppose that a two-dimensional integer array is stored in row-major sequence as in the figure below:

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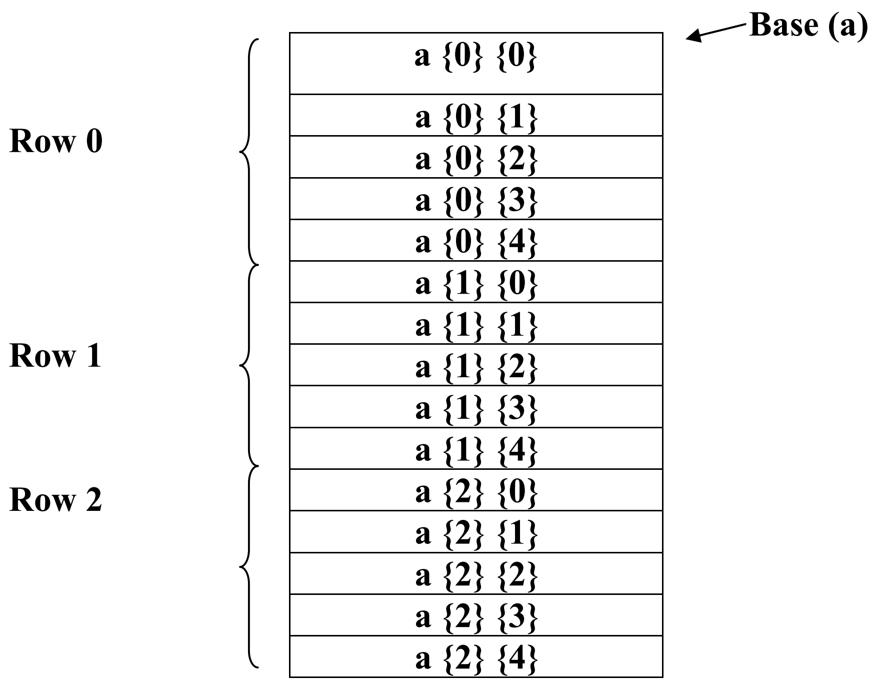

And let we suppose that, for an array are, base (a) is the address of the first element of the array. That is, if ar is declared by

int ar {r1} {r2};

where r1 and r2 are the range of the first and the second dimension, base (ar0 is the address of ar {0} {0}.We also assume that esize is the size of each element in the array. Let us calculate the address of an arbitrary element.

Ar {j1} {j2}

Since the elements is in row j1,its address can be calculated by computing the address the first element of row j1 and adding the quantity j2*esize . but to reach the quantity j2 *esize >But reach the first elements of row j1 (the elemnt cu [j1] [o] .it is necessary to pass thug j1Complet rews, each of which Contains r2 elements ,So the address od the first elements of row j1 is at base (ar) +j1*r2*seize .

Therefore the address of ar [j1] [j2] is at base (ar) + (j1*r2+j2)*esi

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Example

If we have array declared as :

a[3] [s]

So , r1z]and r2 z5 and the address of a [o] [o] is base (a) , let us suppose that each element of the array requires a single unit of storage ,so seize = 1 Then the location of a [2] [u] can be computed by :

base [a] + (ri*r2+j2) *esize

base [a] + (2*5+4) *1

bas[a] + 14

Multidimensional arrays

C also allows arrays with more than two dimension ,for example ,a three – dimensional array

Int b [3] [2] [4];

Implementing One – Dimensional Arrays

A one dimensional array can be implemented easily the C declaration

Int b[100];

Reserves 100 successive memory locations , each large enough to Conation single integer The address of the first location is called the base address of the array b and is denoted by base (b) . Suppose that the Size of each individual element of the array is esize. Then reference to the element b[o] is to the element at location base (b), reference to b[1]is to the element at base (b) + esize , reference to b[2]is the element base (b) +2*esize.

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In general , inference to b [j] is to the element location base (b) +j*esize.

In fast , in the C language an array variable is implemented as a pointer variable . The type of the variable b in the above declaration is "Pouter to an integer " or int *.

An asterisk dose not appear in the declaration because the brackets auto magically imply that the variable is pointer.

If we have the declaration :-

Int * b;

Since b is pointer to an integer , * (b+ j) is the value of j th integer following the I degree location b

For example :-

The C declaration

Int a [100];

Specifies an array of 100 integers . The Smallest element of an array's is dex is called its lower bound and in C is always O , and the highest element is upper bound .

If lower is the lower bound of an array and upper the upper bound , the number of elements in the array , called its range , is given by upper – lower t1 .

For example , in the array, a, declared previously, lower bound is O , the upper bound is 99, al the range is 100.

Using One – Dimensional Arrays

A one dimensional array is used when it is necessary to Keep a large number of items in memory and reference all the items in uniform manner.

Suppose we wish to read 100 integers, find their average , and determine by how much each integer value form that average.

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```
 # define NUMELTS 100
Void main  (     )
{
int num [NUMELTS];
int j ;
int total ;
Float avg ;
Float diff ;
Total = 0 ;
For (j= o ; j < NUMELTS , j + + )
{
Scanf (% d ",tinum [ i ] ) ;
Total + = num [i];
}
Avg=(float) total /  NUMELTS ; print ("Innimber difference" ) ;
For (j = o; i < NUMELTS ; ί + + )
{
diff= num [i ] avg ;
printf ("In % d % £ " ; num [i ] , diff ) ;
}
```

Print f ("In average is : % £" ; avg) ;

b[i] , the elements at location base (b) + ί *esize , is equivalent to the element pointed to by b + ί , which is * (b + ί)

Two – Dimension Arrays

An element of two dimensional array is accessed by specifying two indices : a raw number and column number .

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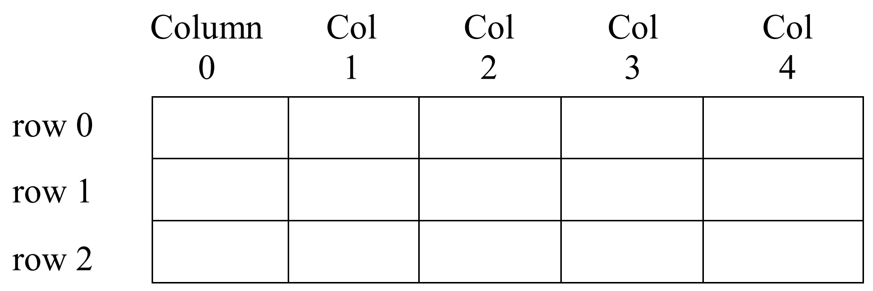

Two-dimensional array

The number of rows or Columns is called the range of the dimension . In the array a, the range of the first dimension is 3 and the Second is 5 .

Array Representation in the Memory

Although it is convenient for the programmer to think of the elements of a two – dimensional array as being organized in a two – dimensional table , the hardware of most Computers has no Such Localities . As array must be stored in the memory of a computer , and the memory is usually linear . To implement a two dimensional array, it is Int C[7] [k] [3] [5] [8] [2] ;

Structures

The second built in Data structure is structure. A structure is a group of variables under one name, in which each variable is identified by its own identifier, each of which is known as a member of structure.

For example, consider the following declaration.

```
Struct:

    Char    first [10];
    Char    midnit;
    Char    last [20];
    }Sname, ename;
```

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This declaration creates two structures variable, sname and ename, each of contains three members: first, midnit, and last.

Alternatively, we can assign a tag to the structures and then declare the variables by means of the tag. For example, consider the following declaration that accomplishes the same thing as the declaration just given.

```
Struct name type:

    Char    first [10];
    Char    midnit;
    Char    last [20];
   };
Struct name type sname, ename;
```

This definition creates a structure tag nametype containing three members. Once a structure tag has been defined, variables sname and ename may be declared.

For maximum program clarity, it is recommended that a tag be declared for each structure and variables than be declare using the tag.

An alternative to using a structure tag is to use the typedef definition. For example:

```
Typedef struct {

    Char    first [10];
    Char    midnit;
    Char    last [20];
    } ;
We can then declare:

Sname, ename,
```

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Once a variable has been declared as a structure, each member within that variable may be accused by specifying the variable name the item's member identifier, thus, the statement.

```
 Printf ("%5", sname.first);
```

Can be used to print the first name in the structure sname, and the statement.

```
Ename. Midnit = "m"
```

Can be used to set the middle initial in the structure ename to the letter.

A member of structure may be declared to be another structure.

```
Struct addrtype {

        Char     straddr [40];
        Char     city [10];
        Char     stafe [3];
        }
```

We may declare anew structure tag nmadtype:

```
Atruct nmadtype {

        struct    nametype  name;
        struct    addrtype   adress;
        } ;
```

Implementing structures

Suppose that under a certain C implementation an integer is represented by feur bytes, a float number by eight, and an array of ten characters by ten byts. Then the declaration.

```
struct   M {
int       X ;
```

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```
float    y;
Char     z[10];
};
```

Then this structure requires 22 bytes to be implemented in the memory.

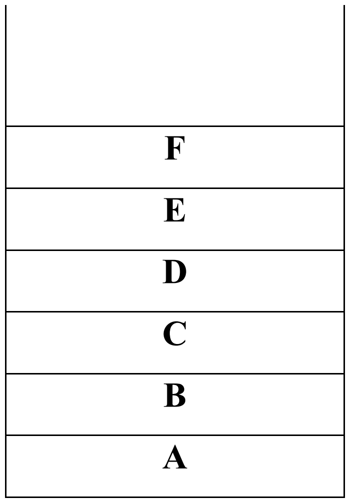
Stack

A stack is an ordered collection of items into which new items may be inserted and from which items may be deleted at one end, called the top of the stack.

The definition of the stack provides for the insertion and deletion of items, of items so that a stack is a dynamic constantly changing object. The definition specifies that a single and of the stack is designated as the stack top. New items may be put on top of the stack, or items which are at the top of the stack may be removed.

In the figure below, F is physically higher on the page then all the other items in the stack, so F is the current top element of the stack, If any new items are added to the stack they are placed on top of F, and if any items are deleted, F is the first to be deleted. Therefore, a stack, is collected a last – in – first – out.

(LIFO) list.



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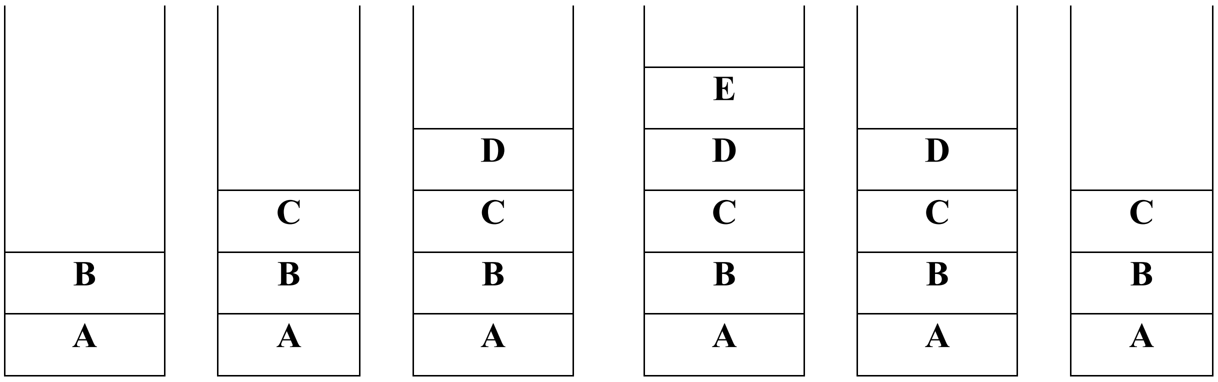
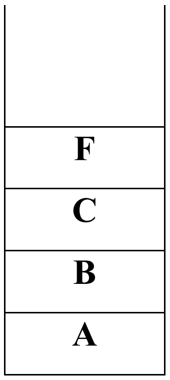
Operations on a stack

The two main operations which can be applied to a stack are given spatial names, when an item is added to a stack, it is pushed onto the stack, and when an item is removed, it is poped from the stack.

Given a stack s, and an item I, performing the operation push (s,i) adds the item I to the top of stack s. similarity, the operation pop(s) removes the top element and returns ir as a function value. Thus the assignment operation I = pop(s); removes the element at the top below is a motion picture of a stack s as it expands (items pushed) and shrinks (item poped) with the passage of item.



push (S,C) push (S,D) push (S,E) pop (S) pop (S)



Push (S,F)

The original idea of the stack is that there is no upper limit on the number of items that may be kept in a stack. Pushing another item onto a stack produces a larger collection of items. When the stack been implemented in a

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represented as an array, therefore we need to give the maximum size of this stack to be shrieked. So, we need as operation called Full (S) (which determines whether or not a stack is full (overflow) to be applied before push operation. On the other hand, if a stack contains a single item and the stack is poped, the resulting stack contains no item and is called an empty stack.

Therefore, before applying the pop operator to a stack, we must ensure that a stack is not empty. The operation empty (s) determine whether or not a stack is empty.

Another operation that can be performed on a stack is to determine what the top item on a stack is without removing it. This operation is written stack top (s) and return the top element of stack s.

I = stacktop (s)

Representing stacks

Before programming a problem solution uses a stack, we must decide how to represent a stack using the data structures that exit in our programming language (C or C^{++}) . the simplest method to represent a stack is to use an array to be home of the stack. During the program execution, the stack can grow and shrink within the space reserved for it. One end of the array is the fixed bottom of the stack, while the top of the stack, Thus another field is needed that, at each point during program execution, keeps tracks of the current position of the top of the stack.

The stack may therefore be declared as a structure containing two objects: an array to hold the elements of the stack, and an integer to indicate the position of the current stack top within the array.

```
# define    stacksize   100
Struct      strack {
        int  top ;
```

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```
            int    item [stacksize] ;
        };
    Struct     stack  s;
```

The empty stack contain s no elements and can therefore, be indicated by top equaling -1 . To initialize a stack s to the empty stack, we may execute.

```
            S  top = -1;
```

The function empty(s) that is used to test whether a stack is empty, may be written as follow:

```
int     empty (struct  stack *st)
        {
        If (st →top = = -1)
            Return (TRUC);
       Else
           Return (FALSE)
       }
```

The function full (s) that is used to test whether a stack is full, may be written as fellow:

```
int     full (struct    stack *ST)
        {
       If (st → top = = maximize -1)
            Return (TRUE);
       Else
      return (FALSE);
     }
```

The function pop that is used to remove the element in the top of the stack, must perform the following three actions:

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1- If the stack is empty, print a warning message and halt execution.
2- Remove the top element from the stack.
3- Return this element to the calling program.

```
int  pop (srtuct stack *ST)
       {
         If (empty (ST))  {
               Cout << "stack underflow" ;
               Exit (q) ;
       }
       Return (ST → item [st → top P-] ;
       }
```

The function push is used to add a new element to the top of the stack. This function must perform the following operations:

1- If the stack if full, print a warning message and halt execution.
2- Add a new element into the top of the stack.

```
Void push (struct  stack *ST, int x)
     {
       If (full (S+)) {
             Cout << "stack is overflow";
              Exit (1);
         }
Else
ST → item [+ + (ST →top)] = x;
Return ;
```

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```
      }
```

The function stacktop (), which returns the top element of a stack without removing it from the stack, may be written as follows:

```
int  stacktop (struct  stack *ST)
   {
    If (empty (ST))  {
       Cout << "stack is underflow";
       Exit (1);
     }
     else
      return (ST → item {ST → top});
     }
```

Converting an expression from index to postfix.

To correct an infix expression to postfix for, we will use an algorithm that uses a stack which may contain: arithmetic operators, parentheses and a spatial delimiter "#".

The description of the algorithm is as follows:

1- Define a function infix priority, which takes an operator, parenthesis, or # as

character	**x**	**/**	**+**	**-**	**(**	**)**	**#**
Returned value	**2**	**2**	**1**	**1**	**3**	**0**	**0**

2- Define another function stack priority, which tacks the same possibility as an argument and returns an integer as:

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character	**x**	**/**	**+**	**-**	**(**	**)**	**#**
Returned value	**2**	**2**	**1**	**1**	**3**	**undefined**	**0**

3- Push # onto opstack as it its first entry.

4- Read the next character from the infix expression.

5- Test the character.

- If the character is an operand, add it to the postfix string.
- If the character is a right parenthesis then pop entries from the stack add the m to the postfix string until a left parenthesis is poped. Discovered both left and right parenthesis.
- If the character is a #, pop all entries that remain in the stack add them to postfix string.
- Otherwise, pop from the stack and add to postfix the operator that have stack priority greater than or equal to the infix priority of the read character, then push the read character to the opstack.

To convert an infix expression to postfix form, we will use the following function:

```
Void convert (struct stack &ST, char exp[80]),
                    Char  post {80}.
       {
        Char       c,op
        int    pos, z, y, po2;
        pos   = po2 = 0;
        push (st, "#");
        do
        {
```

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```
C = exp {po2};
If (isdigit ©)
Post [ pos ++} =C;
Else
If (c == ')')
{
Op = pop (st);
While (op:- '(')
{
Post [pos ++] = op;
Op = pop (st);
}
}
Else
If (C = = '#' )
{
Op = pop (st);
Post[pos + +] = op;
While (op : = '#')
{
Op = pop (st);
Post {pos + +} = op;
} }
Else
{
Op = pop (st);
Z = stack (op);
```

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```
          Y = infixp (c);
          While (z  > = y)
          {
          Post {pos + + } = op;
          } z = stackup (op);
          Push (st, op);
          Push (st, c);
          }
          Po2 + + ;
          }
          While (C ! = '#')'
          For (pos 0; post {pos} ! = '#'; pos + +)
          Cout << post {pos};
          Return;
          }
int  stack P (char  symb)
          {
          Switch (symb)
          {
          Case  '×' : return (2);
          Case  '/ ' : return (2);
          Case  '+' : return (1);
          Case  '-' : return (1);
          Case  '(' : return (3);
          Case  '#' : return (0);
          }
          }
```

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```
int  infix (char  symb)
        {
        Switch (symb)
        {
        Case  '×' : return (2);
        Case  '/ ' : return (2);
        Case  '+' : return (1);
        Case  '-' : return (1);
        Case  '(' : return (0);
        Case  ')' : return (0);
        Case  '#' : return (0);
        Default: cout <<"illegal operation";
                    Exit (1);
        }
        }
```

Example

Convert the following infix expression to postfix using stack:

A + (B /C) #

ch	opstack	postfix	commentary
	#		**Push # to opstack read ch**
A	# \#	**A** **A**	**Add ch to postfix read ch**
+	# # +	**A** **A**	**Push ch to opstack read ch**
(	# + # + **(**	**A** **A**	**Push # to opstack read ch**
B	# + **(** # + **(**	**A** **A B**	**Push # to opstack read ch**
/	# + **(** # + **(**	**A B** **A B**	**Push # to opstack read ch**

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C	**# + (/** **# + (/**	**A B** **A B C**	**Add ch to postfix read ch**
)	**# + (/** **# +**	**A B C** **A B C /**	**Pop and add to postfix until (is reached.** **Read ch**
#	**# +**	**A B C /** **A B C / + #**	**Pop and add to postfix until the opstack is empty.**

Example

Convert the following infix expression to postfix using stack;

((A – (B + C)) * D) / (E +F) #

ch	opstack	postfix	commentary
	#		**Push # to opstack** **read ch**
(	**#** **# (**		**Push # to opstack** **read ch**
(	**#((** **#((**		**Push ch to opstack** **read ch**
A	**#((** **#((**	 **A**	**Add ch to postfix** **read ch**
–	**#((** **#((-**	**A** **A**	**Push # to opstack** **read ch**
(	**#((-** **#((- (**	**A** **A**	**Push # to opstack** **read ch**
B	**#((- (** **#((- (** **#((- (**	**A** **A** **A B**	**Add ch to postfix** **read ch**
+	**#((- (** **#((- (+**	**A B** **A B**	**Push # to opstack** **read ch**
C	**#((- (+** **#((- (+**	**A B** **A B C**	**Add ch to postfix** **read ch**
)	**#((- (+** **#((-**	**A B C** **A B C +**	**Pop and add to postfix until (is reached**
)	**#((-** **#(**	**A B C +** **A B C + -**	**Pop and add to postfix until (is reached**
*****	**#(** **#(***	**A B C + -** **A B C + -**	**Push # to opstack** **read ch**
D	**#(***	**A B C + -**	**Add ch to postfix**

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	#(*	A B C + - D	read ch
)	#(* ′#	A B C + - D A B C + - D *	Pop and add to postfix until (is reached
/	# # /	A B C + - D * A B C + - D *	read ch Push # to opstack
(	# / # / (	A B C + - D * A B C + - D *	Push # to opstack read ch
E	# / (# / (	A B C + - D * A B C + - D * E	Add ch to postfix read ch

E	# / (# / (	A B C + - D * E A B C + - D * E	Add ch to postfix read ch
+	# / (# / (+	A B C + - D * E A B C + - D * E	read ch Push # to opstack
F	# / (+ # / (+	A B C + - D * E A B C + - D * E F	read ch Add ch to postfix
)	# / (+ # /	A B C + - D * E A B C + - D * E F +	read ch Pop and add to postfix until (is reached
#	# /	A B C + - D * E F + A B C + - D * E F + #	read ch Pop and add to postfix until (is reached

The main part of the program is the function eval:

```
Double  eval (char B expr [  ])

{

Char C; int X , position;

Double oproll, operation, value;

Struct stack opndstk;

Opndstk.top = -1;

X = strain (expr);

For (position < X ; position + +)}

C = expr [positisn]
```

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```
If (isdigit (c))
Push (xopndstk, (double) (c- '0'));
Else
{
Opnd 2 = pop (X opndstk);
Opnd 1 = pop (X opndstk);
Value = oper (C, opnd 1, opnd 2);
Push (X opndstk, value);
}  }
Return (pop (X opndstk));
}
```

The function isdigit checks if its argument is s digit:

```
int  isdigit (char synb)
{ return (symb > = '0' X X symb < = 'q');
```

To write program to evaluate a postfix expression, we need four files to be included in our program:

```
# include  < iostrem.h >
# invlude  < stdlib .h >
# include  < math.h >
# include  < string .h >
```

The structure of the stack that will be used is this program:

```
Struct stack {
    int top;
    double item {80}
    } ;
```

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As we need stack in this problem, we need to use the usual operation of stack (push, pop, full, and empty).

In addition to these operations we need additional function:

Double eval (char [ ]);

Double oper (int, double, double);

Int isdigit (char);

The main function is as followe:

```
Void main ( )
{
Char expr (80);
Cout << "enter the expression"
Cin >> expr;
Cout ,< < eval (expr);
```

Applications of stacks

1- Asthmatic Expression Validity Consider a mathematical expression that includes Several Sets of nested parentheses I for example;

7- ((X*((X+y) / (J-3))+y) / (4-2.5))

We want ensure that the parentheses are nickel correctly ; that is we want to check that :

1- There are an equal number of right and left parentheses.
2- Every right parenthesis is preceded by a matching left parenthesis.

Expressions such as

((A+B) or A+B(

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Violate condition 1 , and expressions such as

)A+B(-C or (A+B)) – (C+D

Violate condition 2

To Solue this problem , think of each left parenthesis as opening a scope and each right parenthesis as Closing a scope .

To change the problem slightly , let us assume that there are three different types of Scope delimiters exist These types are indicated by pureness ((and)), brackets ([aol]) , and braces([oal]) . A scope enter must be of the Same type as its scope opener Thus , string such as :

(A+B] , ([A + B)] , [A-(b]

Are invalid.

A stack may be used to Keep track of the types of Scope encrusted . Whenever a scope opener is encountered , it is pushed onto the stack . when never.

A scope ender is encountered , the stack is examine .

- If the stack is empty , the scope ender dose not have a matching opener and the string is invalid.
- If , however , the stack is nonempty , we pop the stack and check whether the popped item corresponds to the scope ender . If a match occurs , we continue . If it does not , the string is invalid .

when the end of the string is Rachael , the stack must be empty; otherwise one or more Scoops have been opened which have not been closed .

figure below , shows the state of the stack after reading in parts of the string :

{X+(Y-[a+b])*c-[(d+e)] / (h-(j – (K-{X+(-[a+b])*c-[(d+e)] / (h-(j-(k-[L-n]))) .

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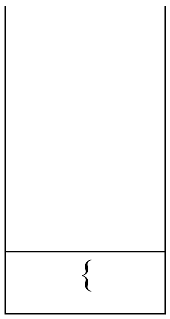
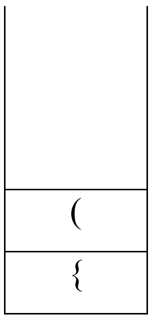
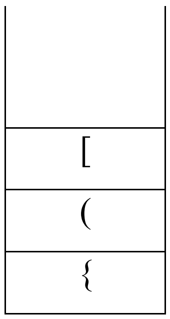


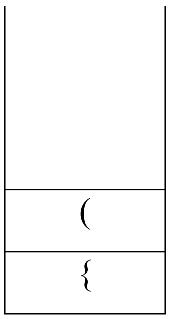
{ …



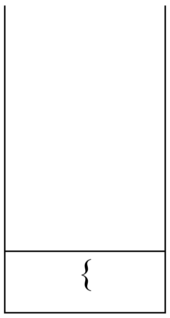
{xt(…



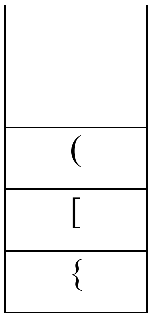
{xt(y-[…



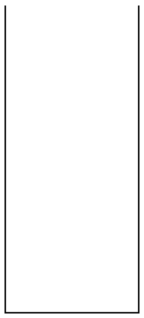
{xt(y-[a+b]…



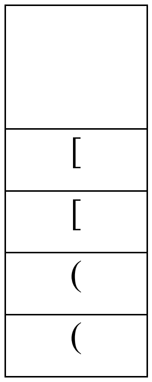
{xt(y-[a+b]…



{xt(y-[a+b]*C-[(



{x+(Y-[a+b]*c-[(d+e]



{xt(y-[a+b]*c-[(d+e)]} / (h-(j-(k-[

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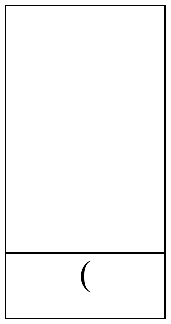

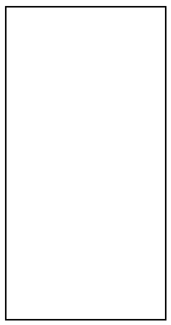

{x+ (y-[a+b]*c-[(d+e)]} / (h-(j-(k-[ℓ - **{x +(y-[a+b]*c-[(d+e)]} / (h-(j-(k-[ℓ -n**

Infix, Postfix , and prefix Expressions

Consider the sum of A and B. we think of applying the operator t" to the operands A and B and write the Sum as A+B . This particular representation is called ifix . There are two alternate notations for expressing the Sam of A and Busing the symbols A, Band t . These are

T A B prefix

A B + postfix

In prefix notation the operator precedes the two operands , in postfix notation the operator follows the two operands , and in infix notation the operand.

Is between the two operands.

The evaluation of the expression A+B*c, as written in standard infix notation , require Knowledge of which of the two operations + or * is to be performed first.

In the case of + and * we Know that mutilation is to be done before addition . Thus A+B*c is interpreter As a (B*C) .

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Foe the Same example , if we want need to write the expression as (A+B)*C .Therefore , Infix notation may require parentheses to specify a decimal or of operations.

Using postfix and prefix notation , the notation, the need for parentheses is eliminated because the operator is placed directly after (before) the two operands to which it applied .

To convent infix expression to postfix forms ,we use the following algorithm :

1- Completely parenthesize the infix expression .
2- Move each operator to the space hold by its corresponding right parenthesis.
3- Remove all parentheses.

We can apply this algorithm to the expression :

A / B$C + D*E – A*C

(((A / (B $ C)) + (D*E)) – (A * C))

ABC$ / DE*+AC*-

The conversion algorithm for infix to prefix specify that , after compactly parenthesizing the infix expression with order of priority , we move each operator to its corresponding left parent .

And after that , delimiting all parentheses

For example :-

(((A / (B $ C)) + (D * E)) – (A*C))

(((A / (B $ C)) + (D * E)) – (A*C))

- + / A$BC *DE*AC

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In the above example , we have consider five binary operations : addition , subtraction , , multiplication division, and exponentiation . The first four are available in C and C^{++} and are dented by the usual operators + ,- , * and / > The fifth , expunction is demotion by \$. The value of the expression A \$ B is a raised to the B power , So that 3\$ 2 is of For these binary operators the following is the order of precedence (highest to lowest) :

Exponentiation

Multiplication / division

Addition / Subtraction

When un parenthesize operators of the Same precedence are scanned , the order is assume to be left to right except in the case of the exponentiation , where the order is assumed to be from right to left . Thus A+B+C means (A+B) +C, whereas A \$ B \$C means A \$ (B\$C) .

Evaluating a postfix Expression

Stacks con be used to evaluate the different expression notation in sedition to converting from one expression notation to another as we will see later.

Here, we consider evaluating postfix expression using stack .

As an example , consider the postfix expansion

623 + - 382 / + * 2 \$ 3 +

To evaluate such expression, we reputedly read characters from the postfix expression. If the character read is can operand , push the value associational with it onto the stack . If it is an operator , pop two values from the stack,

copy the operator to them, and push the result back onto the stack

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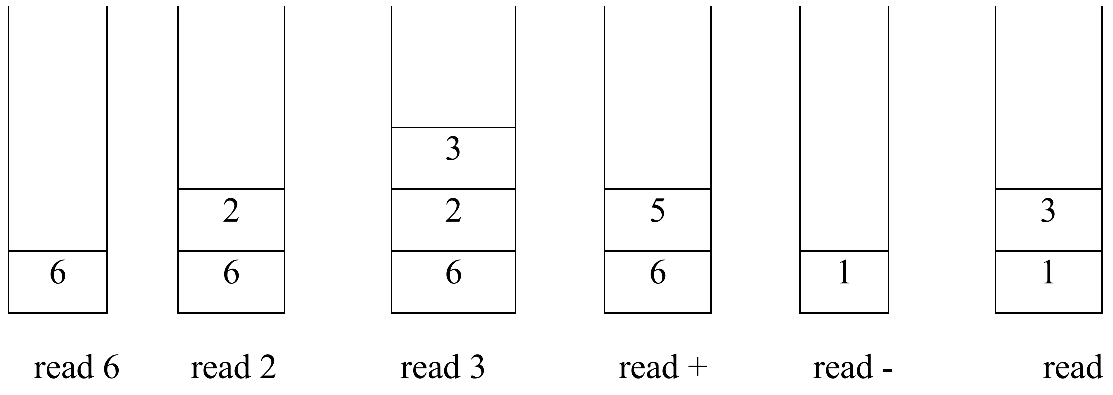

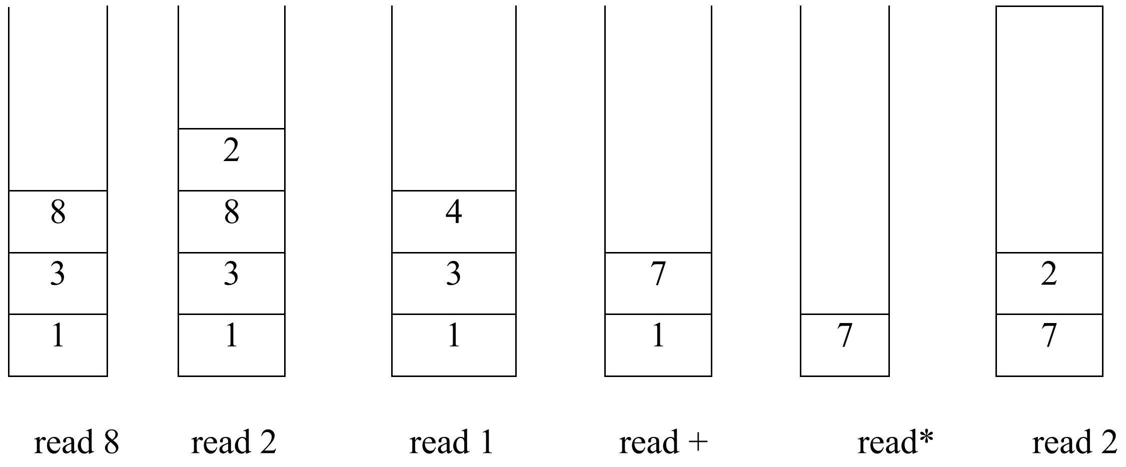

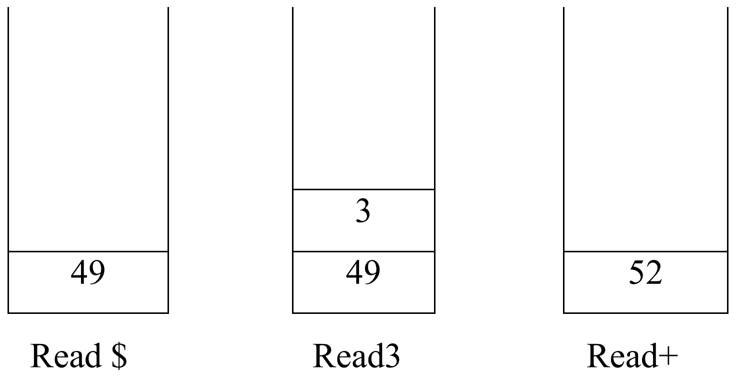

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Queues

A queue is an ordered collection of items from which items may be deleted at one end (collect the front of the queue) and into which items may be inserted at the other end (called the nearer of the queue). The figure illustrates a queue containing there elements A, B and C. A is at the front of the queue and C is at the rear.

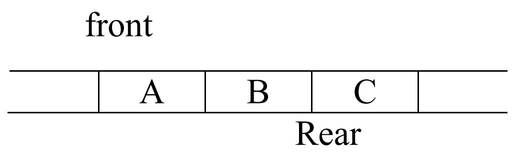

Figure -1-

In figure -2- an element has been deleted from the queue. Since may be deleted only from the front of the queue, A is removed and B is now at the front.

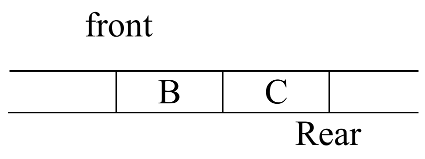

Figure -2-

In figure -3- , when items D and E are inserted , they may be inserted at the rear of the queue.

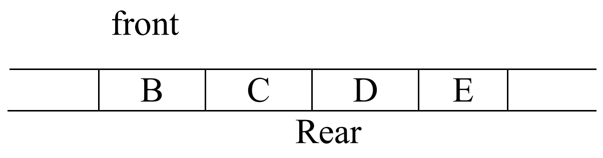

Figure -3-

Initially, the queue is empty. Then H, B, and C have been inserted, then tow items have been deleted into two new items D and E have been inserted. Although there are

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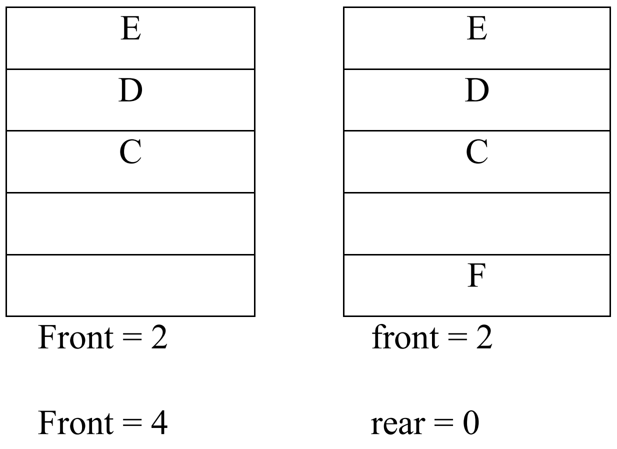
two spaces in the queue array but, we cannot insert a new element to this queue, because of the overflow case is notified when

q. rear = = maxqueue -1

A more efficient queue representation is to treat the array of the queue as a circuited rather than a straight line. That means even if the last element of the array is occupied, anew value can be inserted in the first element of the array as long as that element is empty.

Unfortunately, it is difficult under this representation to determine when the queue is empty. The condition q. rear < q. front is no longer valid as a test for the empty queue.



One may to solve this problem is to establish the conversation that the value of front is the array index immediately preceding the first element of the queue rather than the index of the first element itself. Since rear is the index of last element of the queue, the condition q. front = = q. rear.

The first element inserted into a queue is the first element to be removed. For this reason a queue is sometimes called a FIFO (first – in first – out) list.

Three primitive operations can be applied to a queue. The operation insert (q,x) inserts item x at the rear of the queue q. the operation

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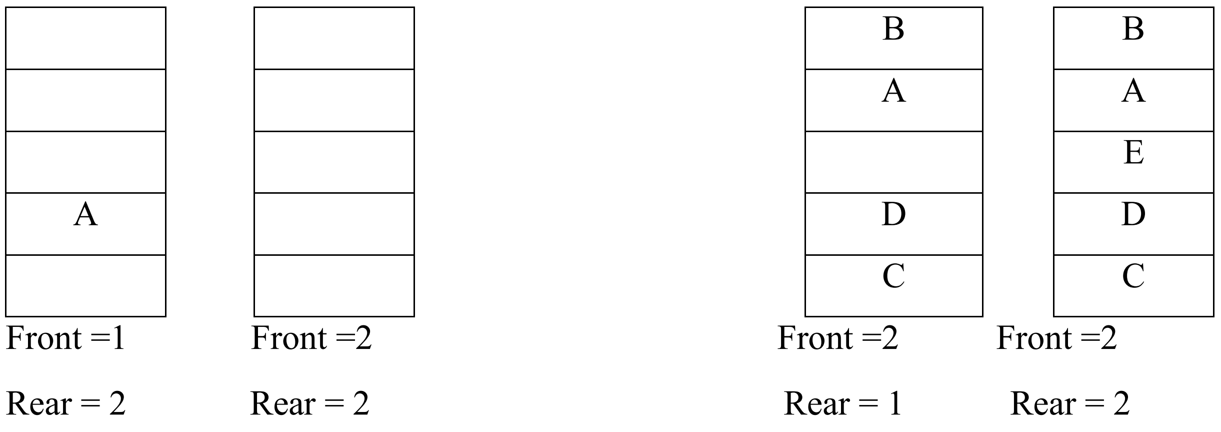
X = remove (a) deletes the front element from the queue q and sets x to its contents. The third operation, empty (a), returns false or true depending on whether or not the queue contains any element.

The insert operation can always be performed since there is no limit to the number of elements a queue may contain, the remove operation, however, can be applied only if the queue is nonempty; there is no way to remove an element from a queue containing no element. The result of an illegal attempt is called underflow. The empty operation is, of course, always application.

Implies that the queue is empty. A queue of integers may therefore be declared and initialized by:

```
# define queue {
    int   items [MAXCUEUE];
    int  front , rear;
    };
    Struct queue q;
    q. front = q. rear = MAXCUEUE – 1;
```

this solution leads a new problem that we cannot distinguish between full and empty queue.



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In figure (a) removing the last element, leaving the queue empty. In figure (b) adding an element to the last free slat in the queue leaving the queue full. The value of front and rear in the two situation are identical.

One solution is to scarifies one element of the array and to allow a queue to grow only as large as one less than the size of the array.

Implementation of queues

The queue can be represented using an array to hold the elements of the queue and to use two variables, front and rear, to hold the positions within the array of the first and last elements of the queue.

Of course using an array, to hold queue introduce the possibility of overflow, if the queue should grow larger than the size of the array.

```
# define MAXCUEUE 100
      Struct  queue {
      int  items { MAXCUEUE}
      int front, rear;
      { q;
```

Initially, q. rear is set to -1 , and q. front is set to 0. The queue is empty whenever q. rear < q. front, and the number of elements in the queue at any time is equal to the value of q. rear –q. front +1.

Let us examine what might happen under this representation, the following figure illustrates an array of five elements used to represent q queue.

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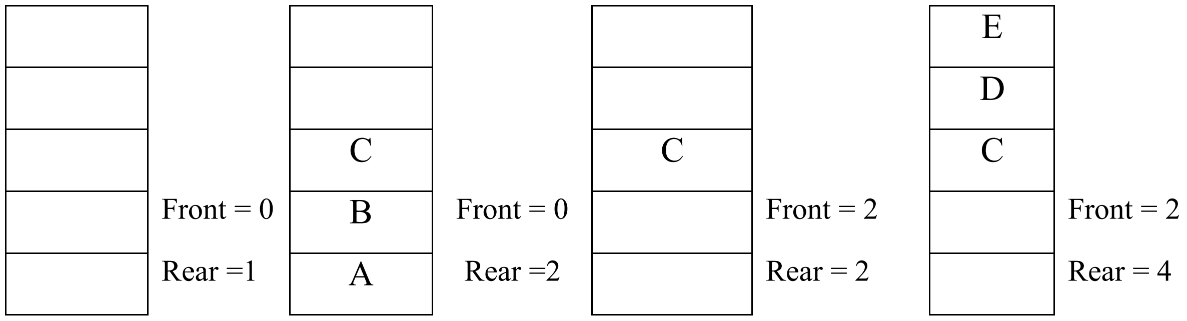
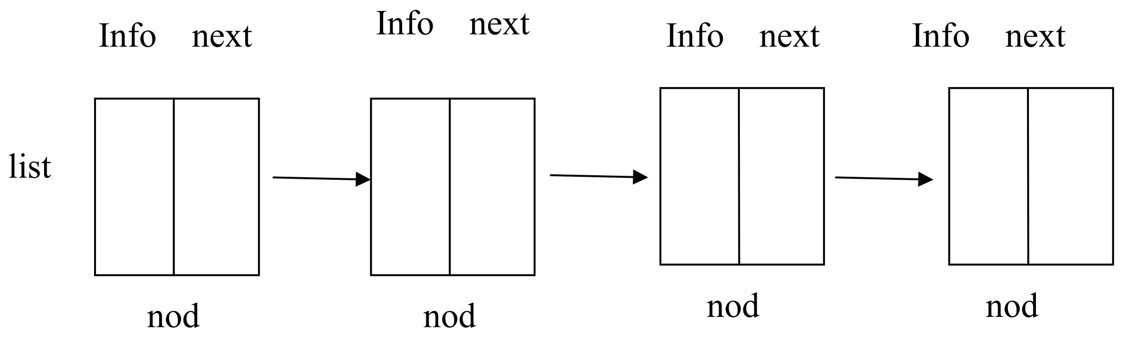


Linked List

The drawback of using sequential storage to represent stacks and queues is that affixed amount of storage remains allocated to the stack or queue even when the structure is actually using a smaller amount or possibly no storage at all. Further, no more than that fixed amount of storage may be allocated, thus introducing the possibility of our flow .

In Sequential representation , the items of a stack or queue are implicitly ordered by Sequential order of storage. Thus if q . ikms[x] represents an element of a queue the next element will be q.items [x+1].

Suppose that the items of a stack or a queue were explicitly ordered , that is each item contained within itself the address of the next item. Such an explicit ordering gines rise to a data structure, which is known as linked list.



Linear Linked

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Each item in the list is called node and contains two fields , an information field and a next address field .

Information field holds an actual element on the list the next field contains the address of the next element in the . Such an adders , which is used to access a particular no de is a pointer .

The entire linked list is accessed from an external pointer list that points to the first node in the list the next field of the last node contains a special value , known as null. The list with no node is Know as null list or empty (the external pointer is unitized to null)

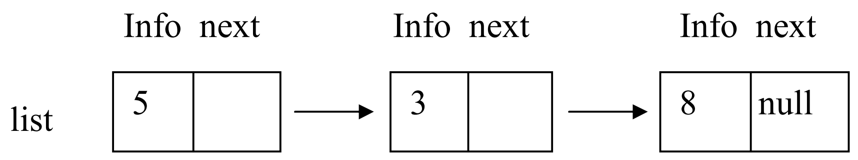
If p is a pointer to a node , node (p) refers to the node pointed to by p ,

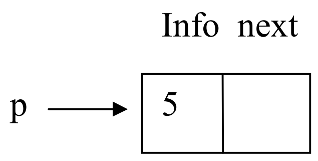
Info (p) refers to the information pointed of the node. Next (p) refers to the address of the next node until its therefore a pointer .

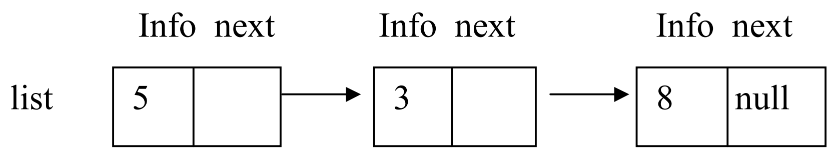
Inserting a removing Nodes from a list

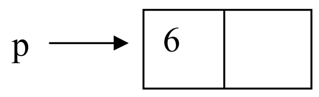
A list is a dynamic data structure . The number of nodes on a list may vary as elements are inserted and removed

Desire to add the integer 6 to the front of that list . the next figure show the steps of adding a new item to the list .









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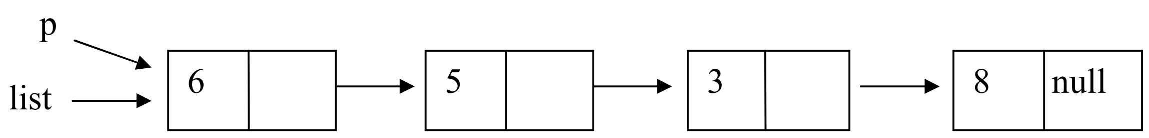

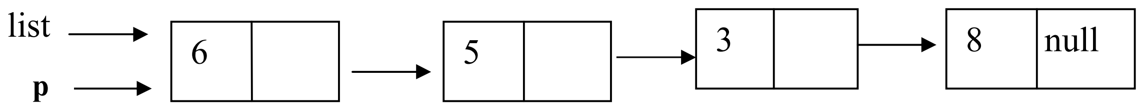

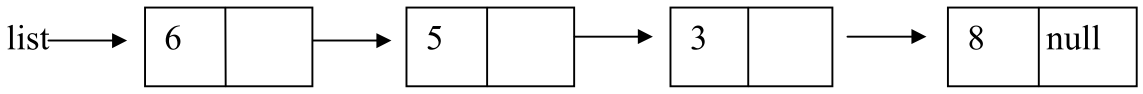

The first step is to obtain an empty node and set the contents of a variable named p to the address of that node . let us assume that the a mechanism to do that is :-

P = getnode ( )

Next step is to insert the integer 6 into the info portion of the newly allocated node :-

Info (p) = 6

The next step is to set the next field of the node since the node is to be added to the front of the list, the node that follows should be the entered first node on the list :-

Next (P) = list ;

Since list is the external pointer , its value must be modified to the address of the new first node of the list .

List = p ;

Putting all steps together , we have an algorithm for adding anew value to the front of a list :-

P = getnode ( ) :

Info (p) = 6 ;

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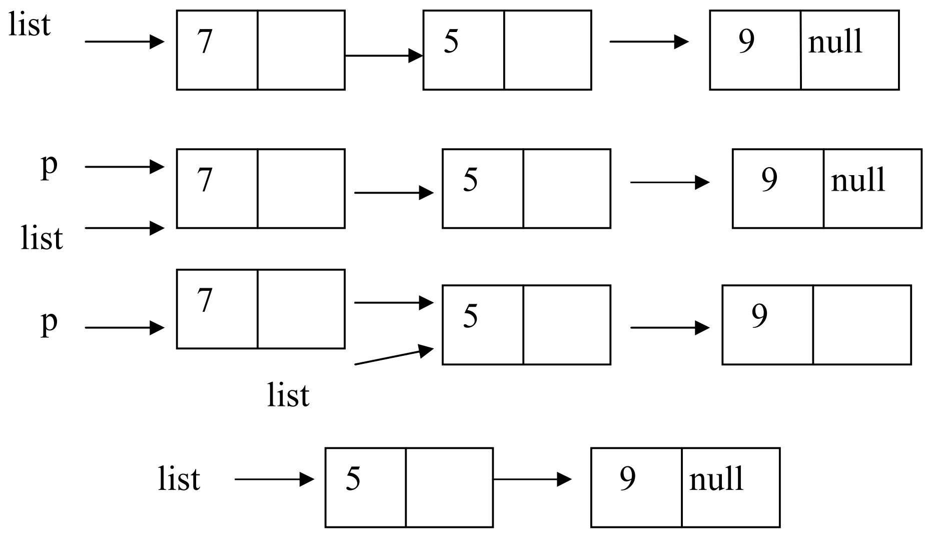
Next (p) =list;

List = p;

The process of removing the first node of a nonempty list and storing the value of its info field into a variable x is as the next figure :-



To remove a node from the list, the following operations are performed :

P = list ;

List = next (p) ;

X= info (p) ;

f reenode (p) ;

The list step is for making node (p) available for reuse .

Mocating and Freeing Dynamic Variables In C a pointer variable to an integer can be created by the declaration

Int * P;

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Once array p has been declared as a pointer to a specific type of object it must be possible to dynamically create an object of that specific type and assign its address to p.

This may be done in C by calling the standard library function malloc (size)

Malloc dynamically allocates apportion of memory of size and returns a pointer to that portion

Consider the declarations

```
Int * pi;
Float * pr ;
```

The statements

```
Pi= (int * ) malloc (size of (int) ;
Pr = (float * ) malloc (Size of (float );
```

Dynamically create the integer variable * pi and the float variable *pr. These Variables ara called dynamic variables.

The operator Size of returns the size, in bytes , of its operand.

malloc (Size of int) allocates storage for an integer, whereas malloc (Size of (Hoat) allocates storage for a floating – point number .

The malloc function return type is void *, So we need to Cast the pointer returned by that function to the required type . we should write .

```
pi= (int *) malloc (size of ) (int).
```

As an example of the use of the function malloc :-

```
# include < stdlib . h >
Void main (   )
{
Int *p ,*q ;
```

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```
Int x ;
P= (int * ) malloc (size of (int) ;
8p=  3;
q = p;
Cout   < <  * p;
 Cout   < <  * q ;
X= 7;
*9=X ;
Cout   < <  * p;
 Cout   < <  * q ;
P= (int *) malloc (size of (int ) ;
*p=5;
 Cout   < <  * p;
 Cout   < <  * q ;
Return ; ?
```

Implantation of Linked list using Dynamic Variables

Recall that a linked list consists of a set of nodes, each of which has two fields: an information field and appointer field to the next node in the list .

In addition , an external points to the first node in the list . the type of a pointer and anode is defined by :

```
Struct node {
int info ;
struct node    * next ;
} ;
Typedef struct node * NODEPTR ;
```

Operation on Linked lists

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There are different types of operations can be implanted to deal with the linked list data structure, such as inserting a new item , removing an item , Search about item ….etc.

Insert a new item to a linked list

1- Insert First : adding an item to the beginning of a linked list .

```
Void insfrst (NODEPTR *Plist , int x)
{
NODEPTR P ;
P= (NODEPTR ) malloc (size of (NODEPTR ) .
 p→ info = X ;
p → next = *plist ;
*plist = p ;
Return;
}
```

2- Insert End : adding an item to the end of a linked list :

```
Void insend (NODEPTR * plist , int X)
{
 NODEPTR p, q ;
 p= (NODEPTR ) malloc (sizeal (NODEPTR ) ;
p→info =X ;
p→next = NULL ;
if (*plist =NULL )
*plist = p;
else {
for (9=*plist ; q→next :NULL ; q=next ) ;
```

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```
q→ next = p ;
}
}
```

3- Place : adding an item to assorted linked list

```
Void place (NODEPTR *plist , int x)
{
NODEPTR p, q, w ;
q= NULL ;
for (p= * plist ; p ! = NULL X > p →info ; p = p want
q= p;
if (q= = NULL )
in first (plist ,x);
else
{
W= ( NODEPTR ) malloc (sizeof (NODEPTR )
W→info = X ;
W→next =q →next ;
q→next =W ;
}
return ;
}
```

Reem of : removes the first node in a linked list removf (NODEPTR *plist)

```
{
Int X ;
 NODEPTR P ;
if  ( *plist = = NULL )
```

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```
{
Cout < < "list is empty " ;
Exit (1) ;
}
P = plist ;
X= p→info ;
*plist = p → next ;
Free (p) ;
return (X) ;
}
```

4- Removl : removes the last node in a linked list int removl (NODEPTR *plist)

```
{
Int X ;
NODEPTR p,q ;
if (*plist = = NULL )
{
Count < <  "list is empty ";
Exit (1) ;
}
q= NULL ;
for (p=plist ; p→next : = NULL ; p=p next
q= p;
X=P→ info ;
If (q =  = NULL )
*plist = NULL :
else
q→ next = NULL ;
```

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```
free (p) ;
return (X) ;
}
```

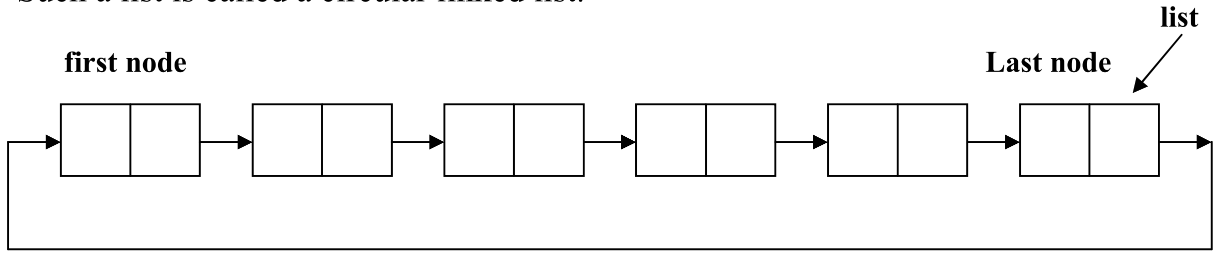
-Search : a function to search about an item into Search (NODEPTR *plist , int item)

```
NODEPTR p ;
For (p=*plist ; p! = NULL ++ I tem ! = p→info ; p= p →
If (p = = NULL )
Return (o) ;
Else
Return (i) ;
```

Circular linked list

Given a pointer P to a node in a linear linked list, we cannot reach any of the nodes that precede the node that is pointed to by P. if a list is traversed, the eternal pointer to the list must be traversed to be able to reference the list again.

Suppose that a small change is made the structure of a linear linked list, so that the next of the last node contains a pointer back to the first node rather than null. Such a list is called a circular linked list.



A circular linked list does not have a natural first end last node. We must, therefore, establish a first and last node by conversion. One useful convention is to let the external pointer to the circular list points to the last node.

Implementation of circular linked lists

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The type of a pointer and a node is defined in the same way as alinear linked list.

```
Srtuct   node {
int   info;srtuct  node  *next;
{;
Typedef struct node *NODEPTE;
```

- Insert first: a function to insert a new node to the beginning of a circular linked list:
- Void insert (NODEPTR *plist, int x)

```
{
NODEPTR    P;
P = (NODEPTR) malloc sizeof  (NODEPTR);
P → info = x;
If (*plist = = NULL)
*plist = P;
Else
P → nxext = P;
}
```

```
Void insert (NODEPTR *plist , int x)
    {
    NODEPTR P;
    P = (NODEPTR) malloc sizeof (NODEPTR);
    P→ info = x;
    If (*plist = =  NULL)
    {
    *list = P;
    }
    Else
    {
    P→ next = (*plist) → next
    (*plist) → next = P;
    *plist = P;
    }
    }
```

- Delete – first: a function to delete the first node in a circular linked list.
- Vint delF (NODEPTR * plist)

```
{
If (*plist = =  NULL)
```

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```
        {
        Cout << "the list is empty";
        Exit (1) ;  }
        P = (*plist) → next;
        X = P → info;
        If (P = = *plist)
        *plist = NILL;
        Else
        (*plist) → next = P → next;
        Free (P);
        Return (x);
        }
```

Delete – last: a function to delete the last n node I a circular linked list

```
       Int delet-L (NODEPTR *plist)
       {
       NODEPTR P, a;
       If (*plist = =  NILL)
       {
       Cout << "the list is empty";
       Exity (1);
       Q = NULL;
       For (P = (*plist) → next; P ! = *plist; = P→ next)
       X = P → info;
       If (q = = NULL)
       *plist = NULL
       Else
       {
       q → next = P → next;
       *plist = q;
       }
       Free (P);
       Return (X);
       }
```

Recursive function to linear linked list

- Print: a recursive function to print the elements of linear linked list.

```
Void print (NODEPTR)

{

If (P ! = NULL)
```

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```
{
Cout << P → info;
Print (P → next);
}
```

Reprint: a recursive function to print the elements of a linear linked list in reverse order.

```
Void Rprint (NODEPTR  P)
{
If (P ! = NULL)
{
Rprint (P → next);
Cout << P → info;
}
```

Delete – value: a function to delete a specific value in a linear linked list.

```
Void  delete (NODEPTR *plist, int x)

    {
    NODEPTR  P,q;
    If (*plist = = NULL)
    {
    Cout << "empty list";
    Exit (1);
    }
    q= NULL;
for (P = *plist; P ! = NULL X X P → info != X; P = P → nest

    q = P;
    if (q = =  NULL)
```

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```
        { *plist = P → next; free (P);}
        Else
        If (P = = NULL)
        {
        Cout << "the value is not found";
        }
        Else
        q → next = P → next;
        free(P);
        }
        }
```

Remix: a function to delete all nodes whom info field contains the value x.

```
Void remix (NODEPTR) *plist, int x)
{
NODEPTR P,q;
q = NULL; P = *plist;
while (P ! = NULL)
{
If (P → info = = x)
{
P = P → next;
If (q = = NULL)
{/ * remove first node of the list */
Free (*plist)
*plist = P;
}
Else
```

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```
{
q → next = P = q →next;
}
Else
{ q = P;
P = P → next;
}
}
}
```

The function free is used to free storage of a dynamically allocated variable. The statement:

```
Free (P);
```

Makes any future reference to the variable *P illegal. Calling free(P) makes the storage occupied by *P a variable for reuse , if necessary.

To illustrate the use of free function, consider the following program:

```
# include < stablib.h>

Void main (  )

{

int *p, *q;

P = (int X) malloc (sized (int));

*P= 5;

q = (int *) malloc (sized (int));

*q = 8;

Free (P);
```

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```
P = q;
q = (int *) malloc (sized (int));
*q = 6;
Cout << *P;
Cout << *q;
Return;
}
```

Recursion

Recursion is a programming tool that allows the user to write functions that calls themselves.

Factorial function

Factorial function plays an important role in mathematics and statistics. Given a positive integer, n, factorial is defined as the product of all integers between n and 1. For example 5 factorial equals 5 * u * 3 * 2 * 1 = 120. In mathematics, the exclamation mark (!) is often used to doubt the factorial function. We may write the definition of this function as follows:

n! = 1 if n = = 0

n! = n * (n-1) * (2-2) * …. * 1 if n > 0

as an example for this definition:

0! = 1

1! = 1

2! = 2 * 1

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3! = 3 * 2 * 1

u! = u * 3 * 2 * 1

……

For any a > 0 we see that n! equals (n-1) !. multiplying n by the product of all integers from n-1 to / yields the product of all integers from n to 1. We may therefore define

0! = 1

1! = 1 * 0!

2! = 2 * 1!

3! = 3 * 2 !

u! = u * 3!

….

So we an write our mathematical notation as:

n! = 1   if (n = =0)

n! = n (n-1) ! if n > 0

this function may appear quite strange, since it once 0! Has been defined, defining 1! As 1   0! Is not circular at all. Similarly, once 1! Has been defined, defining 2! As 2 1! Is straight word.

Therefore , we must evaluate 3 ! Repeating this process , we have that

s^{-} =s^{-}*u!

u!=u * 3!

2!=2 * 1!

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1! = 1*0!

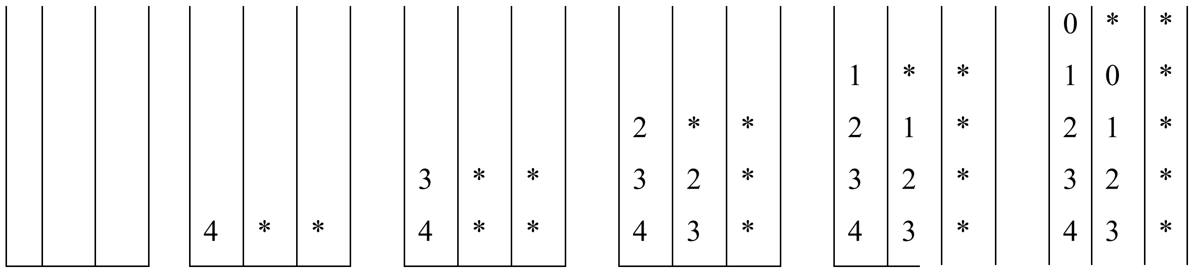
0!=1

The recursive algorithm to computer n ! may be directly translated into a C function as follows :

```
int fact (int n)

{

Int x, y ;

if  (n = = 0)

return (1) ;

X = n-1 ;

y = fact (x) ;

return (n * y)

}
```

When this function is called in the main program and also with in itself , the compiler uses a stack to Keep the successive generations of call variables and parameters. This stack is maintained by the C system and is invisible to the user . Each time that a recursive function entered , anew allocation of its variables is pushed on top of the stack .

When the function returns, the stack is propel .



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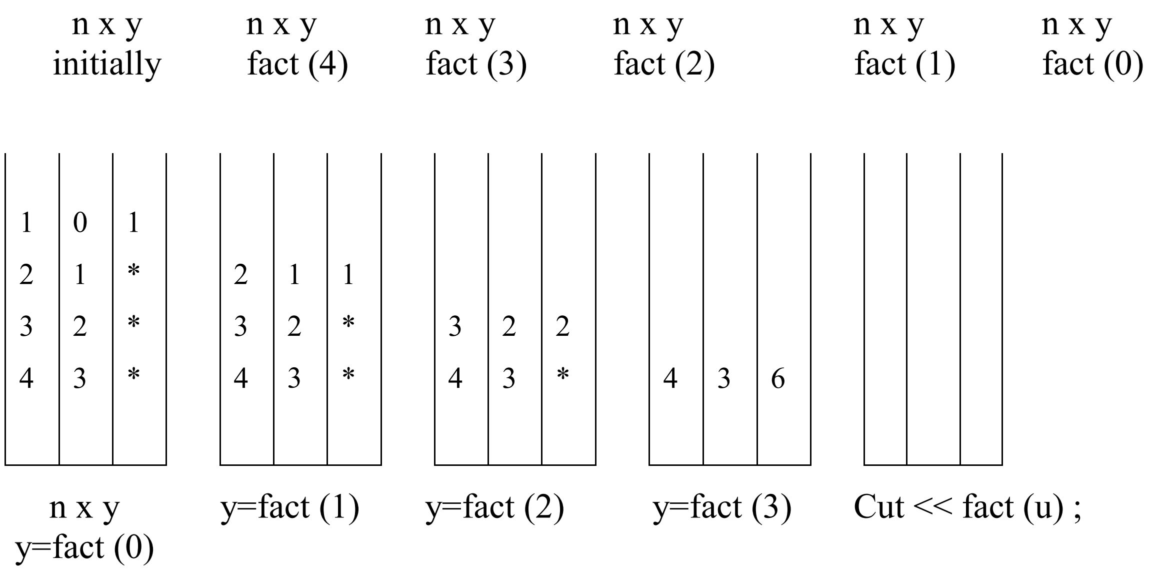
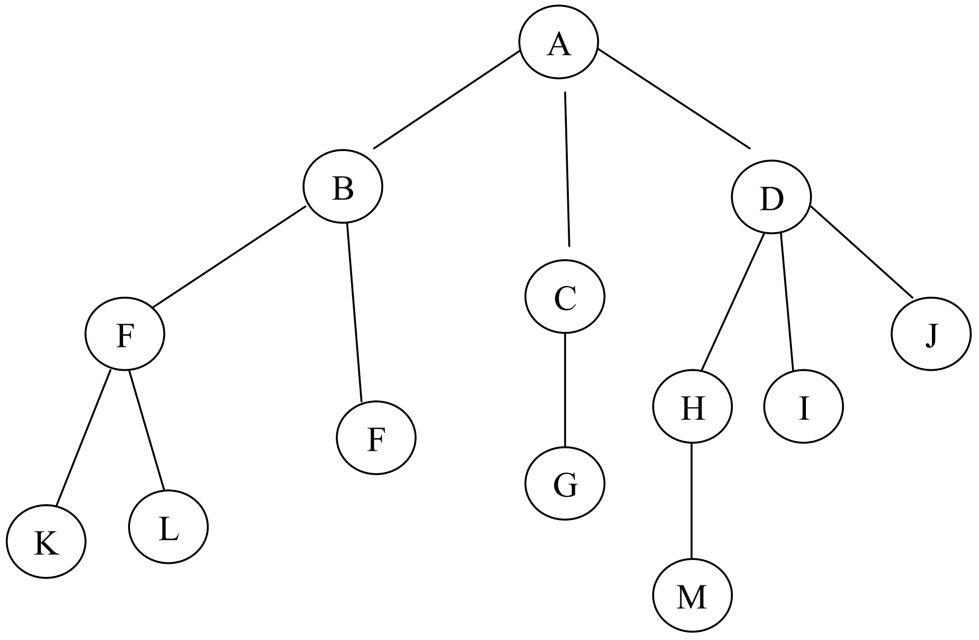


Three

A tree is a data structure that has hierarchal relationships between its individual data items .



- The higher node a of the tree is the root .

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- The nodes B, C and D which are directly Connected to the root node are the children of the root .
- The children of a given parent is the set of sub trees .
- The link between a parent and its child is called branch .
- The root of the tree is the ancestor of all nodes in the tree.
- Each node may be the parent of any number of nodes in the tree.
- Anode with no a subset of a tree which is itself a tree.
- The number of sub trees of a node is called its degree (the degree of A is 3) and the degree of the tree is the maximum degree of the nodes in the tree .
- The root of the tree has level 0 , and the level of any other node in the tree is one more than the level of its father .
- The depth of the tree is the maximum level of any leaf in the tree .

Binary tree

A binary tree is the tree that is characterized by the fact that any node can have at most two branches (i.e) there is no nod with degree greater than two).

A binary may be empty or consist of a root and two disjoint binary tree called the left subtree and the right subtree .

Binary Search trees

The binary search tree is a binary tree in which the left child , if there is , of any node Contains a smaller value than does the parent node and the right child , if there is, contains a larger value than the parent node .

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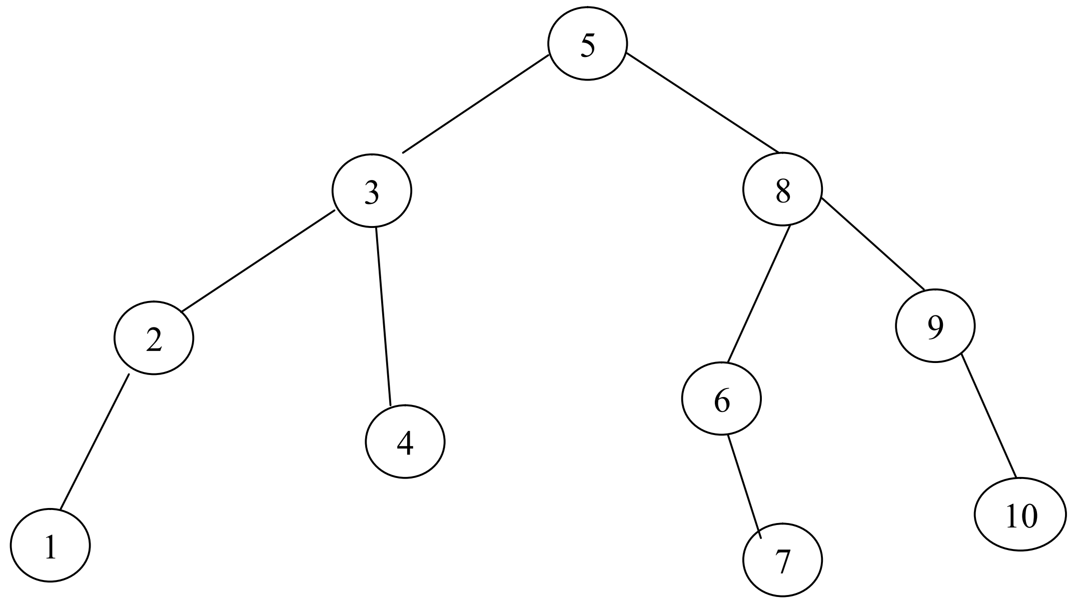
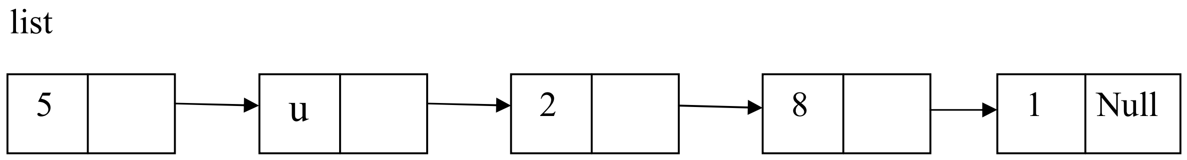


Advantages of using Binary Search Trees

One of the drawbacks of using linked lists to store ordered informations , is the time it takes to search along the list to find any value .

For example , if we have the following linked list :



To find the value L , we must make a sequential traversal of all the nodes in the list .

The binary Search tree provides us with a structure that retains the flexibility of the linked list, while allowing quicker access to any node in the list .

Implementation of Binary Search tree

There are two methods to implement binary tree Structure :

1- Linear representation : which does not require the use of the pointers.
2- Linked representation : uses pointers.

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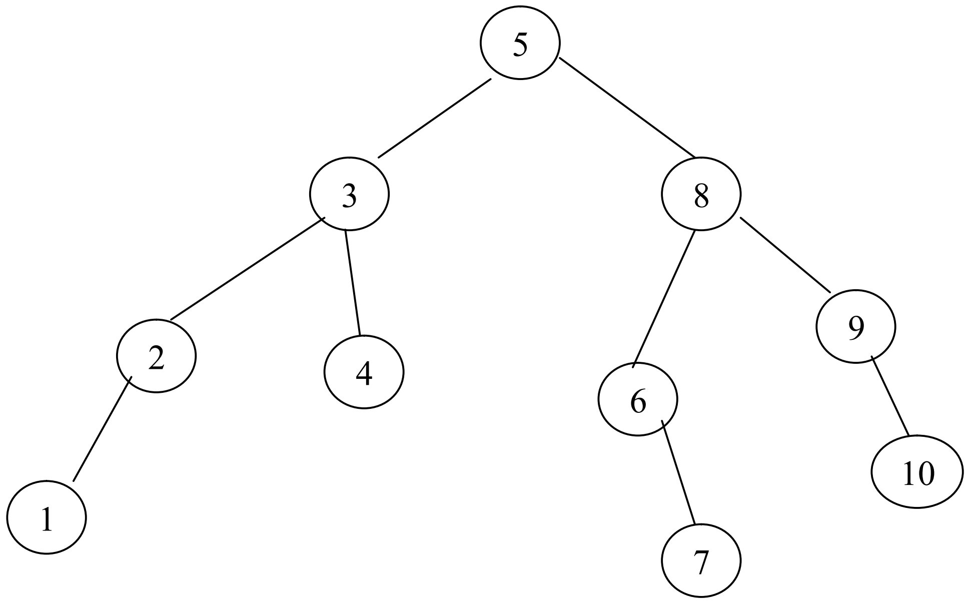
Linear Representation

The linear representation method of a binary Search tree uses a one – dimensional array of size (2^{d+1}-1) where s is the depth of the tree. In the following tree , d =3 and this tree require an array of size (2^{3+1}-1) = 15 to be represented .



Once the size of the array has been determine , the following method is used is represent the tree :

1- Store the root in the 1st location of the array .
2- If anode is in the1st location of the array , Store its left child at location (2n) , and its right child at location (2n+1) .

The main advantages of this method are :

- Its simplicity and the fact that , given a child node, its parent node can be determined immediately .

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If a child node is at location N in the array, then its parent node can be determined immediately . If a child is at location N in the array, then its parent node is at location N / 2 .

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
5	3	8	2	4	6	9	1	-	-	-	-	7	-	10

The disadvantages of this method:

- Insertion and deletion of a node causes Considerable data monument up and down the array , using an excessive amount of processing time , because insertions and deletions are the major data processing activities .
- Wasted memory location.

Linked Representation of a Binary Search Tree

Because each node in a binary tree may have 2 children , anode in a linked representation has 2pointer fields , one for each child , and one or more data fields containing specific information about the node itself . when anode has no children the corresponding pointer fields are NULL.

As in a linear linked list, the first node in the tree is pointed to by an external pointer.

Operations on binary search trees

- Insert: add a new node to a binary search tree.
- Search: search for a node at the binary search tree.
- Delete: delete a node from the binary search tree.
- Print: prints all elements in the binary search tree.

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Linked implementation of a binary search tree.

```
        Struct  node {

        Int  key;

        Char *n;

        Struct  node  * lft;

        Struct  node  *right;

       }

Typedef struct node *NODEPTR;


        -insertion function

        Void insert (NODEPTR  *root, int x. char *name)

        {

        NODEPTR p,q, nwnode;

        nwnode = (NODEPTR) malloc (sizeof (NODEPTR));

        nwnode → key = x;

        nwnode → n = name;

        nwnode → left = NULL;

        nwnode → right = NULL;

        P = *root;   q = NULL;

        While (P! = NULL)

        {
```

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```
Q = P;
If (P → key > x)
P = P → left;
Else
P = P → right;
}
If (q = = NULL)
Root = newnode;
Else
If (q → key >x)
q → left = nwnode;
else
q → right = newnode;
}
```

- Search function

This search function return a pointer to the node that have a specific value.

```
NODEPTR search (NODEPTR *root, int keyvalue)
    {
    NODEPTR P;
    Int valueintree = 0;
    P = *root;
    While (P ! = NULL xx  ! b Valueintree)
    {
    If (P → key = keyvalue)
```

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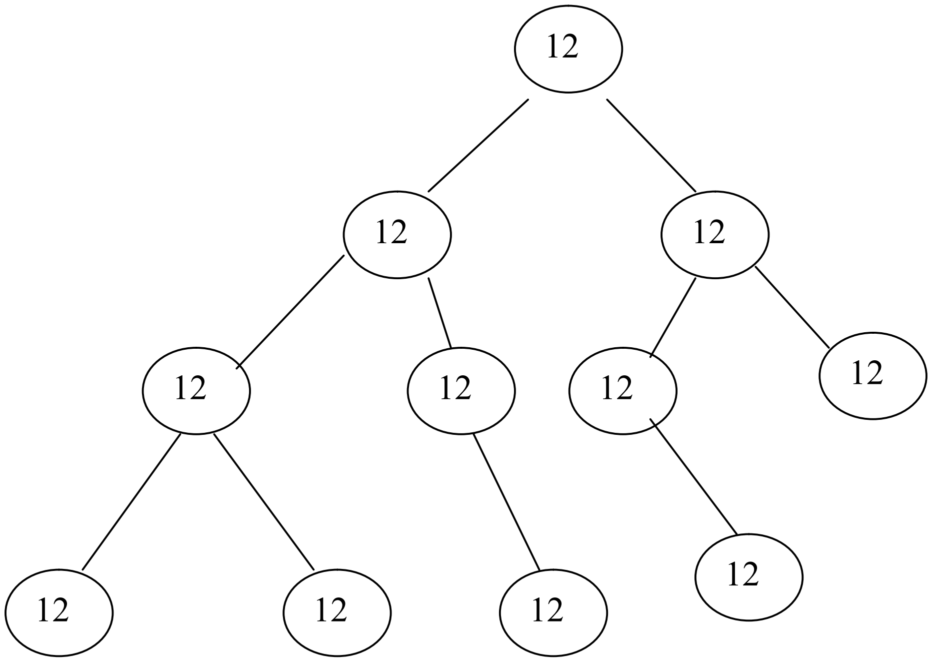
```
Valueixtree = 1;
Else
If (P → key < keyvalue)
P = P → left;
Else
P = P → right
}
Return (P);
}
```

- Print tree functions

To print the information of nodes within a tree we need to visit eachof these nodes and then print its information. There are three different method to visit the tree nodes, each of them prints nodes information in different order.

1- In order print function (left – root – right)

These method means traverse and print from the smallest to the largest values. We first need to print the roots left subtree, then we print the value I the root node finally print the value in the root's right subtree.



Inorder print = 2 5 6 7 10 11 12 15 18 25 45

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```
Void inorder (NODEPTR  P)
{
If (P → left);
Cout << P → key ;
Inorder (P → right);
}
```

2- Preorder print function (Root - left - right)

Preorder method traverse end print each node information before its left and right subtrees. Therefore, the information of the tree in the previous example are print as follows:

Preorder print: 12 7 5 2 6 10 11 25 15 18 45

```
Void preorder (NODEPTR P)
{
If (P !: NULL)
{
Cout << P → key;
Preorder (P → left);
Preorder (P → right);
}
}
```

3- Postorder print function (left – right – root)

Postorder method traverse and print each node information after its left and right subtree. The information of the same example of the previous two methods are print as follows:

Postorder = 26 5 11 10 7 18 15 45 25 12

```
Void postorder (NODEPTR P)
```

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```
{
If (P ! = NULL)
{
Postorder (P → left);
Postorder (P → right);
Cout << P → key;
}
}
```

Search Algorithms

Before consider specific search techniques, let define some terms. A table or a file is group of elements, each of which is called a record. Associated with each record is a key, which is used to differential among different records .

For every file there is at least one set of keys (possible more) that is unique (that is, no two records have the same key). Such a key is called primary key. For example, if the file is stored as an array, the index within the array of an element is a unique external key for that element .

A searching algorithm is an algorithm that accepts an argument a and tries to find a record whose key is a. The algorithm may return entire record or, more commonly; it may return a pointer to that record. It is possible that the search for a particular argument in a table is unsuccessful; that is, there is no record I the table with that argument as its key .

Types of Search Algorithms

There are many types of search algorithms, searching large amount of data to find one particular piece of information, in this research list the algorithms related with proposal algorithm.

Sequential Search

This simplest form of a search is the sequential search. This search is applicable to a table organized either as an array. Let assume that k is an array of n keys, k(0) through k(n-1), and r an array or records, r(0) through r(n-1), such that k(i) is the key

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of r(i). Let assume that key is a search argument. If wish to return the smallest integer i such that k(i) equals key if such an i exists and -1 otherwise .

An example: Figure 1 shows an array, seven elements long, containing numeric values. To search the array sequentially, may use the algorithm of sequential search. The maximum number of comparisons is 7, and occurs when the key we are searching for is in A[6]. Average case complexity of Search, is O(n), where n is the size of array[5].

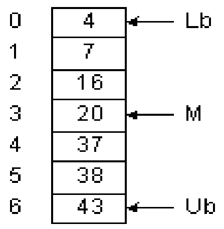

Figure 1: An Array

The algorithm for doing sequential search for above example is as follows:

```
    int function SequentialSearch (Array A, int Lb, int Ub, int Key);
    begin
      for i = Lb to Ub do
        if A(i) =  Key then
          return i;
      return -1;
  end;
```

Binary Search

A fast way to search a sorted array is to use a binary search. The idea is to look at the element in the middle. If the key is equal to that, the search is finished. If the key is less than the middle element, do a binary search on the first half. If it's greater, do a binary search of the second half .

The advantage of a binary search over a linear search is astounding for large numbers. for an array of a million elements, binary search, O($\log_2$ N), will find the

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target element with a worst case of only 20 comparisons. Sequential search, O(N), on average will take 500,000 comparisons to find the element

The algorithm for doing binary search in figure 1 is as follows :

```
   int function BinarySearch (Array A, int Lb, int Ub, int Key);
   begin
     do forever
     M = (Lb + Ub)/2;
     if (Key < A[M]) then
       Ub = M - 1;
    else if (Key > A[M]) then
      Lb = M + 1;
    else
     return M;
    if (Lb > Ub) then
     return -1;
 end;
```

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