Data structures and Algorithms
Basic Data structures

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Outline

1. Basic concepts

2. Array

3. Lists

4. Stacks

5. Queues

Basic concepts

- Data Types
    - set of values
    - data representation
    - set of operations
- Abstract Data Types (ADT)
    - set of values
    - set of operations

Data Types: primitive data types in C

- **Built-in data types In C programming language**

Type	Bits	Minimum value	Maximum value
byte	8	-128	127
short	16	-32768	32767
char	16	0	65535
int	32	-2147483648 $= -2^{31}$	3247483647 $= 2^{31} - 1$
long	64	-9223372036854775808	9223372036854775807
float	32		
double	64		

- Operations on primitive data types: $+$, -, *, /, ...

ADT

ADT	Object	Operations
List	nodes	insert, remove, find,...
Graphs	nodes, edges	findPath, Search,...
Stack	elements	push, pop, isEmpty,...
Queue	elements	enqueue, dequeue, isEmpty,...
Binary tree	nodes	traversal, find, ...

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Array

- Collection of elements of similar data type
- Elements are stored sequentially
- Each elements of the array is accessed via its index
- An array can have one or more dimensions

Example

```
int a[1000];
int b[100][100];
typedef struct MyStruct{
  int value;
  MyStruct* ptr;
};
MyStruct x[10];
```

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4 Stacks

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Lists

- List ADT implements an **ordered** collection of values (each value can appear several times)
- Notations
  - L: list of objects
  - x: an object
  - p: position type
  - $END(L)$: function that returns the position after the position of the last element of the list
- Operations
  - Insert(x, p, L): insert element x at position p of the list L
  - Locate(x, L): return the position of x in L
  - Retrieve(p, L): return the element at position p in L
  - Delete(p, L): remove element at position p in L
  - Next(p, L): return the position after the position p in L
  - Prev(p, L): return the position before the position p in L
  - MakeNull(L): set L to empty list and return $END(L)$
  - First(L): return the first position in L
  - PrintList(L): print all elements of L in the order they appear in L

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List - implementation

- Array-based
    - Elements located in contiguous blocks in memory
    - **Delete** and **Insert** operations are costly
- Pointer-based (linked list)
    - Collection of nodes that not necessarily locate in contiguous blocks
    - Single linked list: Each node contains the element (data) and a reference (pointer) to the next node
    - Doubly linked list: Each node contains the element (data), a reference to the previous node and a reference to the next node

Array-based implementation

Insertion and **Deletion**

```

int a[10000];
int n;// size of the list, elements are a[1], a[2], ..., a[n]
void insert(int x, int pos){
  for(int i = n; i >= pos; i--)
    a[i+1] = a[i];
  a[pos] = x;
  n = n + 1;
}

void del(int k){
  for(int i = k; i <= n-1; i++)
    a[i] = a[i+1];
  n = n - 1;
}
```

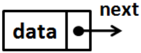
Array-based implementation

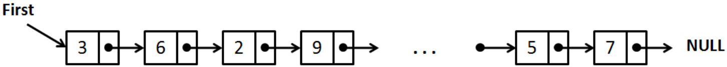
MakeNull and **PrintList**

```
void makeNull(){
  n = 0;
}
void printList(){
  for(int i = 1; i <= n; i++)
    printf("%d ",a[i]);
  pritnf("\n");
}
void retrieve(int k){
  return a[k];
}
int end(){
  return -1;
}
int locate(int x){
  for(int i = 1; i <= n; i++)
    if(a[i] == x)
      return i;
  return end();
}
```

Pointer-based implementation

Single linked list: representation





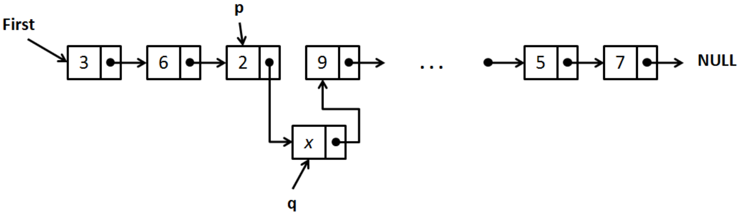
```
typedef int ElementType;

struct PointerType{
  ElementType data;
  PointerType* next;
};

PointerType* first = NULL;
```

Pointer-based implementation

Single linked list: Insertion



Pointer-based implementation

Single linked list: Insertion

```
PointerType* insertAfter(ElementType x, PointerType* p){
  // insert an element x into the position after p
  PointerType* q;
  q = new PointerType;
  q->data = x;

  if(first == NULL){
    q->next = NULL;
    first = q;
  }else{
    q->next = p->next;
    p->next = q;
  }

  return q;
}
```

Pointer-based implementation

Single linked list: Deletion

```
void del(PointerType* p){
  if(p == first){
    PointerType* tmp = first->next;
    delete first;
    first = tmp;
  }else{
    PointerType* pi = first;
    while(pi != NULL && pi->next != p)
      pi = pi->next;
    if(pi != NULL){
      pi->next = p->next;
      delete p;
    }
  }
}
```

Pointer-based implementation

Single linked list: **PrintList** and **MakeNull**

```
void printList(){
  PointerType* p = first;
  while(p != NULL){
    printf("%d ",p->data);
    p = p->next;
  }
  printf("\n");
}
PointerType* makeNull(){
  while(first != NULL){
    PointerType* tmp = first ->next;
    delete first;
    first = tmp;
  }
  return NULL;
}
```

Pointer-based implementation

Single linked list: Previous

```
PointerType* prev(PointerType* p){
  PointerType* tmp = first;
  while(tmp != NULL){
    if(tmp->next == p)
      return tmp;
    tmp = tmp->next;
  }
  return NULL;
}
```

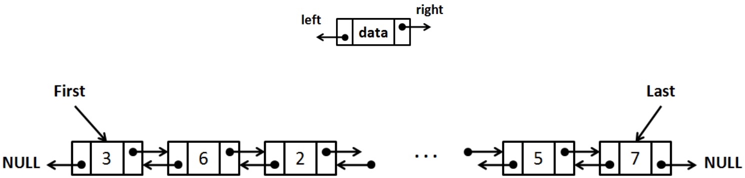
Pointer-based implementation

Single linked list: Locate

```
PointerType* locate(ElementType x){
  PointerType* p = first;
  while(p != NULL){
    if(p->data == x)
      return p;
    p = p->next;
  }
  return NULL;
}
```

Pointer-based implementation

Doubly linked list: representation

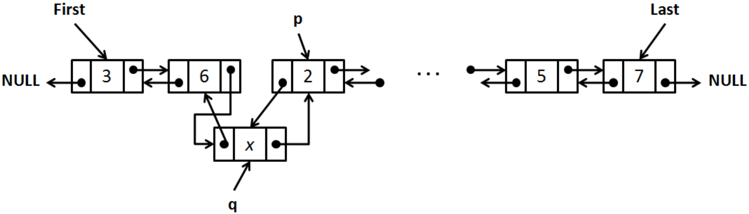


```
struct Node{
  int data;
  Node*  left;
  Node* right;
};

Node* first = NULL;
Node* last = NULL;
```

Pointer-based implementation

Doubly linked list: Insertion (insert an element at a position pointed by a pointer p)



Pointer-based implementation

Doubly linked list: Insertion (insert an element at a position pointed by a pointer p)

```
void insertAt(int x, Node* p){
  Node* q = new Node;
  q->right = p;
  q->data = x;
  Node* p1 = p->left;
  if(p1 != NULL)
    p1->right = q;
  q->left = p1;
  p->left = q;
}
```

Pointer-based implementation

Doubly linked list: Insertion (insert an element to the end of the list)

```
void insertToEnd(int x){
  Node* p = new Node;
  p->data = x;
  if(first == NULL){
    p->left = NULL;
    p->right = NULL;
    first = p;
    last = p;
  }else{
    p->right = NULL;
    p->left = last;
    last->right = p;
    last = p;
  }
}
```

Built-in List in C++

- Manual: http://www.cplusplus.com/reference/list/list/
- Fundamental methods
    - empty()
    - size()
    - push_front()
    - pop_front()
    - push_back()
    - pop_back()
    - insert()
    - erase()
    - clear()

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2 Array

3 Lists

4 Stacks

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Stacks

- Stack ADT: An ordered list in which all insertions and deletions are made at one end (called top)
- Principle: the last element inserted into the stack must be the first one to be removed (**Last-In-First-Out**)
- Operations
  - Push(x, S): push an element x into the stack S
  - Pop(S): remove an element from the stack S, and return this element
  - Top(S): return the element at the top of the stack S
  - Empty(S): return true if the stack S is empty

Linked list-based implementation

```
struct Node{
  char info;
  Node* next;
};

Node* top = NULL;// pointer to the top of the stack


int stackEmpty(){
  if(top == NULL)
    return 1;
  else
    return 0;
}
```

Linked list-based implementation

```
void push(char x){
  Node* p;
  p = new Node;
  p->info = x;
  p->next = top;
  top = p;
}

char pop(){
  char x = top->info;
  Node* p = top;
  top = top->next;
  delete p;
  return x;
}
```

Application: Parentheses matching

- ()([]){}: consistent
- ()()[{): not consistent
- [](){[])[]: not consistent

Application: Parentheses matching

```
int checkMatch(char x, char y){
  if(x == '(' && y == ')') return 1;
  if(x == '[' && y == ']') return 1;
  if(x == '{' && y == '}') return 1;

  return 0;
}
```

Application: Parentheses matching

```
int check(char X[], int n){
  for(int i = 0; i < n; i++){
    if(X[i] == '(' || X[i] == '[' || X[i] == '{')
      push(X[i]);
    else{
      if(X[i] == ')' || X[i] == ']' || X[i] == '}'){
        if(stackEmpty()) return 0;
        else{
          char x = pop();
          if(checkMatch(x,X[i]) == 0) return 0;
        }
      }
    }
  }
  if(stackEmpty()) return 1; else return 0;
}
```

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Queues

- Queue ADT: An ordered list in which the insertions are made at one end (called tail) and the deletions are made at the other end (called head)
- Principle: the first element inserted into the queue must be the first one to be removed (**First-In-First-Out**)
- Applications: items do not have to be processed immediately but they have to be processed in FIFO order
  - Data packets are stored in a queue before being transmitted over the internet
  - Data is transferred asynchronously between two processes: IO buffered, piples, etc.
  - Printer queues, keystroke queues (as we type at the keyboard), etc.

Queues

- Operations
    - Enqueue(x, Q): push an element x into the queue Q
    - Dequeue(Q): remove an element from the queue Q, and return this element
    - Head(Q): return the element at the head of the queue Q
    - Tail(Q): return the element at the tail of the queue Q
    - Empty(Q): return true if the queue Q is empty

Built-in Stack and Queue in C++

- Stack (manual: http://www.cplusplus.com/reference/stack/stack/)
  - empty: Test whether the stack is empty
  - size: Return size
  - top: Access next element
  - push: Add element
  - pop: Remove element
- Queue (manual: http://www.cplusplus.com/reference/queue/queue/)
  - empty: Test whether the queue is empty
  - size: Return size
  - front: Access next element
  - back: Access last element
  - push: Insert element
  - pop: Delete next element

Queues: palindrome strings checking

- A palindrome string is the string that reads the same forward and backward
- Example: MADAM, NOON, RADAR, etc.
- Problem: check whether a given string is palindrome
    - Use queue and stack

Queues: palindrome strings checking

```
#include <stdio.h>
#include <queue>
#include <stack>
#include <string.h>
using namespace std;
int main(int argc, char** argv){
  char* s = argv[1];
  queue<char> Q;
  stack<char> S;
  for(int i = 0; i < strlen(s); i++){
    Q.push(s[i]);     S.push(s[i]);
  }
  while(!Q.empty()){
    if(Q.front() != S.top()){
      printf("not palindrome\n");
      return 0;
    }
    Q.pop();     S.pop();
  }
  printf("palindrome\n");
}
```