Chapter 1. Basic Concepts

Fundamentals of Data Structure in C

Chapter 1. Basic Concepts

1.1 OVERVIEW: System Life Cycle

❖ Sysem Life Cycle for Moblie phone

Requirement specification
Analysis
Design
Implementation
Testing

1.1 OVERVIEW: System Life Cycle

- **Software development process**
  - Requirement specification
    - A set of specifications that define the purpose of the project
    - Describe input and output
  - Analysis
    - Top-down
    - Buttom-up

1.1 OVERVIEW: System Life Cycle

- Design
  - *Data objects* that the program needs
    - *Abstract data type*
  - *Operations* performed on the data objects
    - *algorithm specifications*
  - Language independent

1.1 OVERVIEW: System Life Cycle

- Refinement & Coding
  - Choose representations for the data objects
  - Write algorithms for each operation on them
  - The order is crucial

    ➔ because a data object's representation can determine the efficiency of the algorithms related to it.

- Verification
  - Correctness proofs
  - Testing
  - Error removal

1.2 Pointers and Dynamic Memory Allocation

Pointers

- & : the address operator
- * : the dereferencing (or indirection) operator

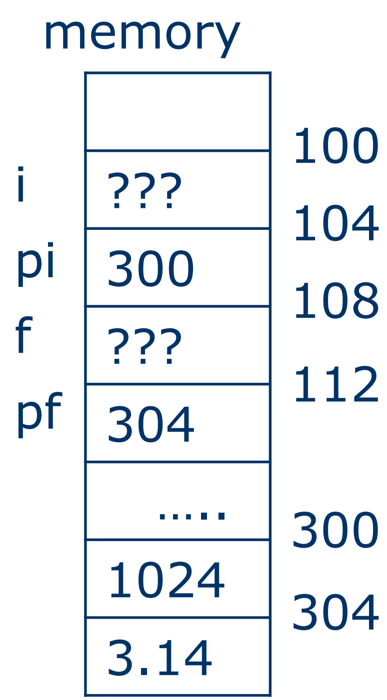
usage

- int i, *pi;
- pi = &i;
- i = 10; *pi = 10;
- if (pi == NULL) …   /* equals   if (!pi)   */

1.2 Pointers and Dynamic Memory Allocation

```
int i, *pi;
float f, *pf;
pi = (int *) malloc(sizeof(int));
pf = (float *) malloc(sizeof(float));
*pi = 1024;
*pf = 3.14;
printf("an integer = %d, a float = %f\n", *pi, *pf);
free(pi);
free(pf);
```

Program 1.1: Allocation and deallocation of memory



1.2 Pointers and Dynamic Memory Allocation

- **A more robust version for *malloc()***

```
if ((pi = (int *) malloc(sizeof(int))) == NULL ||
    (pf = (float *) malloc(sizeof(float))) == NULL)
{fprintf(stderr, "Insufficient memory");
 exit(EXIT_FAILURE);
}
```

or by the equivalent code

```
if (!(pi = malloc(sizeof(int))) ||
    !(pf = malloc(sizeof(float))))
{fprintf(stderr, "Insufficient memory");
 exit(EXIT_FAILURE);
}
```

1.2 Pointers and Dynamic Memory Allocation

❖ A convenient way of using *malloc()*

```
#define MALLOC(p,s) \
    if (!((p) = malloc(s))) {\
        fprintf(stderr, "Insufficient memory"); \
        exit(EXIT_FAILURE);\
    }

MALLOC(pi, sizeof(int));
MALLOC(pf, sizeof(float));
```

1.3 Algorithm Specification

Definitions of algorithm

- An *algorithm* is a finite set of instructions that, if followed, accomplishes a particular task.
- All algorithms must satisfy the following criteria:

  a. input (≥ 0)

  b. output (> 0)

  c. definiteness

  d. finiteness

  e. effectiveness

1.3 Algorithm Specification

- **How to describe an algorithm?**
  - Use a natural language like English
  - Use graphic representations called flowcharts
  - Pseudo Code
  - Program language

  - In this text,
    - Mostly in C
    - Occasionally in a combination of English and C

Find Max in Array

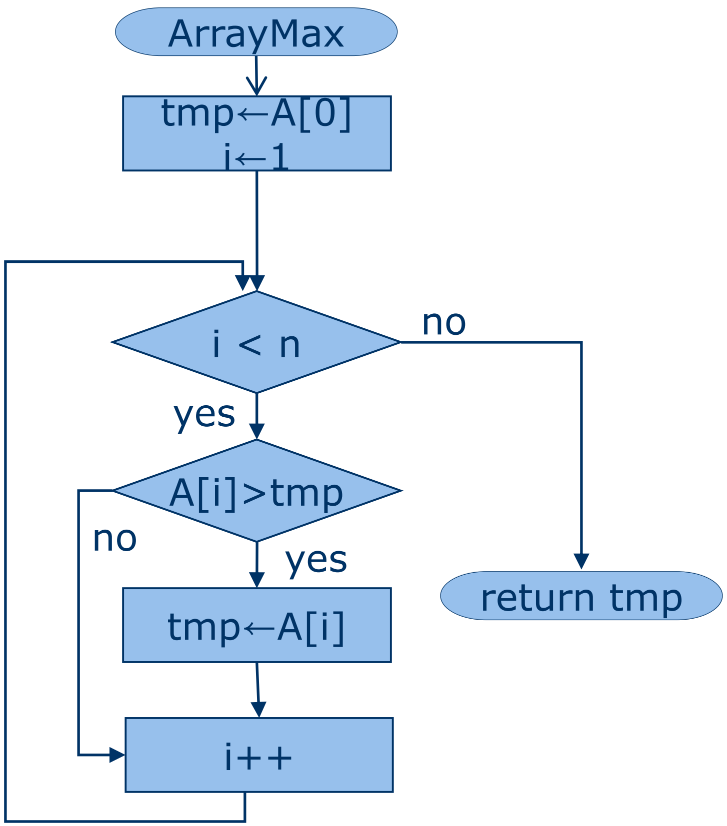
- Use a natural language like English

ArrayMax (A, n)

1. Copy the first element of array A to variable tmp
2. The following elements in array A are compared to tmp in turn, and if larger, copied to tmp
3. Returns tmp if all elements in array A are compared

Find Max in Array

Use graphic representations called flowcharts



Pseudo Code

```
ArrayMax(A,n)

  tmp ← A[0];
  for i←1 to n-1 do
          if tmp < A[i] then
                  tmp ← A[i];
  return tmp;
```

Translating a Problem into an Algorithm

Description of a problem

- Devise a program that sorts a set of $n \geq 1$ integers.

A simple solution

- From those integers that are currently unsorted, find the smallest.
- Place it next in the sorted list.

Translating a Problem into an Algorithm

First attempt at deriving a solution

- Assume that the integers are stored in an array, *list*

```
for (i = 0; i < n; i++) {
  Examine list[i] to list[n-1] and suppose that the
  smallest integer is  at list[min];

  Interchange list[i] and list[min];
}
```

Program 1.2: Selection sort algorithm

Translating a Problem into an Algorithm

Interchanging *a* and *b*

- function
  - swap(&a, &b)

```
void swap(int *x, int *y)
{/* both parameters are pointers to ints */
    int temp = *x;    /* declares temp as an int and assigns
                          to it the contents of what x points to */
    *x = *y; /* stores what y points to into the location
                    where x points */
    *y = temp; /* places the contents of temp in location
                    pointed to by y */
}
```

Program 1.3: Swap function

- macro

  #define SWAP(x, y, t) ((t)=(x), (x)=(y), (y)=(t))

  SWAP(a, b, temp) // Macro works with any data type

#include <stdlib.h>

```
#include <stdio.h>
#include <math.h>
#define MAX_SIZE 101
#define SWAP(x,y,t) ((t) = (x), (x)= (y), (y) = (t))
void sort(int [],int); /*selection sort */
void main(void)
{
  int i,n;
  int list[MAX_SIZE];
  printf("Enter the number of numbers to generate: ");
  scanf("%d",&n);
  if( n < 1 || n > MAX_SIZE) {
    fprintf(stderr, "Improper value of n\n");
    exit(EXIT_FAILURE);
  }
  for (i = 0; i < n; i++) {/*randomly generate numbers*/
    list[i] = rand() % 1000;
    printf("%d  ",list[i]);
  }
  sort(list,n);
  printf("\n Sorted array:\n ");
  for (i = 0; i < n; i++) /* print out sorted numbers */
    printf("%d  ",list[i]);
  printf("\n");
}
void sort(int list[],int n)
{
  int i, j, min, temp;
  for (i = 0; i < n-1; i++)  {
    min = i;
    for (j = i+1; j < n; j++)
      if (list[j] < list[min])
        min = j;
    SWAP(list[i],list[min],temp);
  }
}
```

Program 1.4: Selection sort

Example 1.2 [Binary search]

❖ Problem description

- Assume that we have $n \geq 1$ distinct integer that are *already sorted* and stored in the array list. That is, $list[0] \leq list[1] \leq \ldots \leq list[n-1]$.

- We must figure out if an integer *searchnum* is in this list. If it is, we should return an index, *i*, such that $list[i] = searchnum$. If it is not present, we should return -1.

Binary search

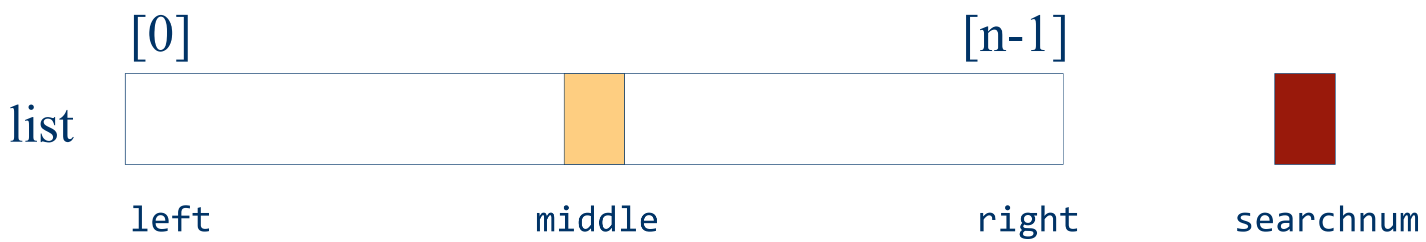
❖ A solution

- Compare *list*[*middle*] with *searchnum*

(1) searchnum < list[middle] : set *right* to *middle*-1

(2) searchnum = list[middle] : return *middle*

(3) searchnum > list[middle] : set *left* to *middle*+1



Binary search

```
while (there are more integers to check ) {
   middle = (left + right) / 2;
   if (searchnum < list[middle])
      right = middle - 1;
   else if (searchnum == list[middle])
            return middle;
         else left = middle + 1;
}
```

Program 1.5: Searching a sorted list

Two subtasks :

(1) determining if there are any integers left to check

(2) comparing *searchnum* to *list*[*middle*]

Binary search

Comparison

- function

```
int compare(int x, int y)
{/* compare x and y, return -1 for less than, 0 for equal,
     1 for greater */
   if (x < y) return -1;
   else if (x == y) return 0;
        else return 1;
}
```

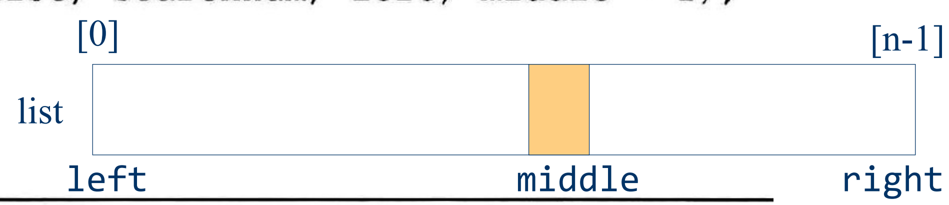
Program 1.6: Comparison of two integers

- macro

```
#define COMPARE(x,y) (((x) < (y)) ? -1: ((x) == (y))? 0: 1)
```

Binary search

```
int binsearch(int list[], int searchnum, int left,
                                         int right)
{/* search list[0] <= list[1] <= ... <= list[n-1] for
    searchnum. Return its position if found. Otherwise
    return -1 */
   int middle;
   if (left <= right) {
      middle = (left + right)/2;
      switch (COMPARE(list[middle], searchnum)) {
         case -1: return
            binsearch(list, searchnum, middle + 1, right);
         case 0 : return middle;
         case 1 : return
            binsearch(list, searchnum, left, middle - 1);
      }
   }
   return -1;
}
```



Program 1.8: Recursive implementation of binary search

1.4 Data Abstraction

- **[Definition] A *data type* is a collection of *objects* and a set of *operations* that act on those objects.**
  - All *programming languages* provide at least a minimal set of *predefined data types*, plus the ability to construct new, or *user defined data type.*

1.4 Data Abstraction

❖ Ex) data type int in C

- Objects
  - { 0, +1, -1, …, INT_MAX, INT_MIN}
  - Representation : 2 byte or 4 bytes of memory
- Operations
  - Arithmetic operators { +, -, *, /, % }
  - Testing for equality/inequality { ==, >, >= , <, <= }
  - Operation that assigns an integer to a variable {=}

1.4 Data Abstraction

- **[Definition] An *abstract data type* is a data type that is organized in such a way that**
  - the specification of the objects and the specification of the operations on the objects *is separated from* the representation of the object and the implementation of the operations.
- ***An abstract data type is implementation-independent.***

1.4 Data Abstraction

Categories of operations of an ADT

- Creator/constructor: These functions create a new instance of the designated type.
- Transformers: These functions also create an instance of the designated type, generally by using one or more other instances.
- Observers/reporters: These functions provide information about an instance of the type, but they do not change the instance.

1.4 Data Abstraction

- **Categories of operations of integer ADT**
  - **Creator/constructor :**
    - int i;
  - **Transformers :**
    - 4+5
    - 10*20
  - **Observers/reporters**
    - Sizeof(i)

1.4 Data Abstraction

ADT *NaturalNumber* is

objects: an ordered subrange of the integers starting at zero and ending at the maximum integer (*INT_MAX*) on the computer

functions:

for all $x, y \in$ *NaturalNumber*; *TRUE*, *FALSE* $\in$ *Boolean*
and where $+$, $-$, $<$, and $==$ are the usual integer operations

NaturalNumber Zero( )	::=	0
Boolean IsZero(x)	::=	**if** (x) **return** *FALSE* **else return** *TRUE*
Boolean Equal(x, y)	::=	**if** ($x == y$) **return** *TRUE* **else return** *FALSE*
NaturalNumber Successor(x)	::=	**if** ($x ==$ *INT_MAX*) **return** x **else return** $x + 1$
NaturalNumber Add(x, y)	::=	**if** (($x + y$) <= *INT_MAX*) **return** $x + y$ **else return** *INT_MAX*
NaturalNumber Subtract(x, y)	::=	**if** ($x < y$) **return** 0 **else return** $x - y$

end *NaturalNumber*

ADT 1.1: Abstract data type *NaturalNumber*

Nicklaus Wirth

- data structure = data type + storage structure
- program = data structure + algorithm

- **Overview: System Life Cycle**
- **Pointers and Dynamic Memory Allocation**
- **Algorithm Specification**
- **Data Abstraction**