

CONFIDENTIAL

C Programming Basic – week 6

Searching

Lecturers :

Tran Hong Viet

**Dept of Software Engineering
Hanoi University of Technology**

Topics of this week

- Search algorithm
 - Sequential searching
 - Sentinel
 - Self organized searching





Why Search ?

- Everyday life -We always Looking for something – builder yellow pages, universities, hairdressers
- Computers can search for us
- World wide web –different searching mechanisms, yahoo.com, ask.co.uk, google.com
- Spreadsheet –list of names –searching mechanism to find a name
- Databases –use to search for a record -select * from ..
- Large records –1000s takes time -many comparison slow system –user wont wait long time



Sequential search (Linear search)

- Visit all the elements of array from the beginning
- Compare the key with each element of a list (or of an array).
- If the search item is found, its index (that is its location in array) is returned. If search is unsuccessful, -1 is returned
- Note the sequential search does not require the list elements to be in any particular order

Sequential Search

```
int LinearSearch (T M[], int N,  
                  T X) {  
    int k = 0;  
    while (M[k] != X && k < N)  
        k++;  
    if (k < N) return (k);  
    return (-1);  
}
```

Exemple

```
#include<stdio.h>

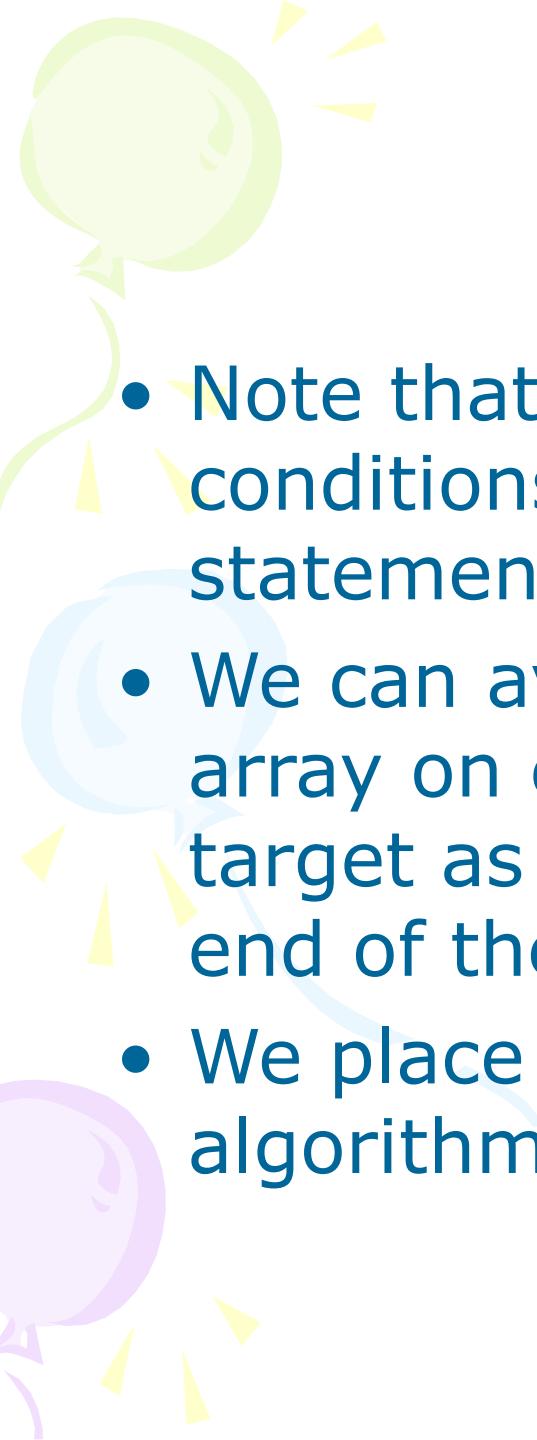
int sequential_search(char *items, int count, char key)
{
    register int t;

    for(t=0; t < count; ++t)
        if(key == items[t]) return t;
    return -1; /* no match */
}

int main(void){
    char *str = "asdf";

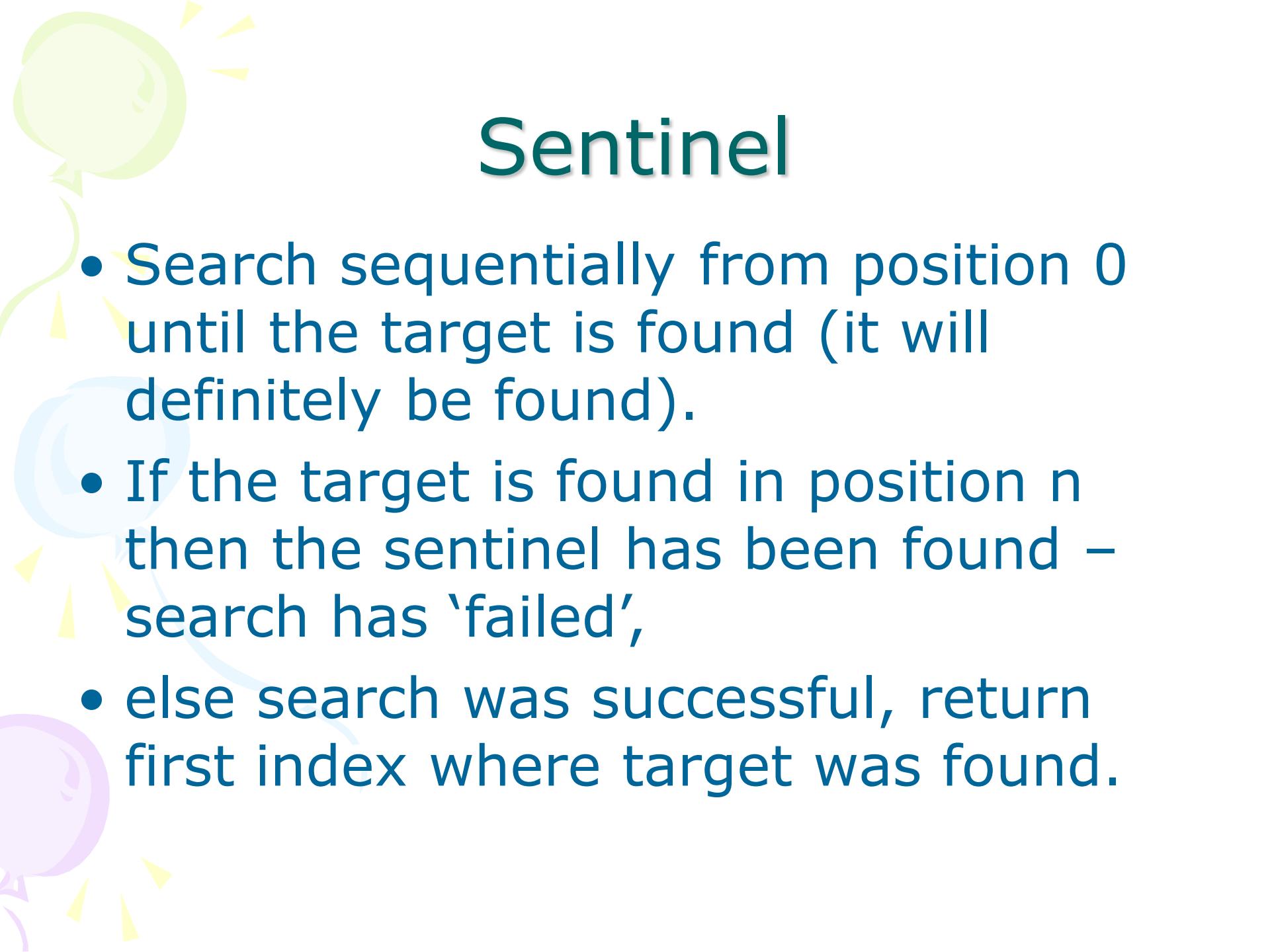
    int index = sequential_search(str, 4, 's');

    printf("%d", index);
}
```



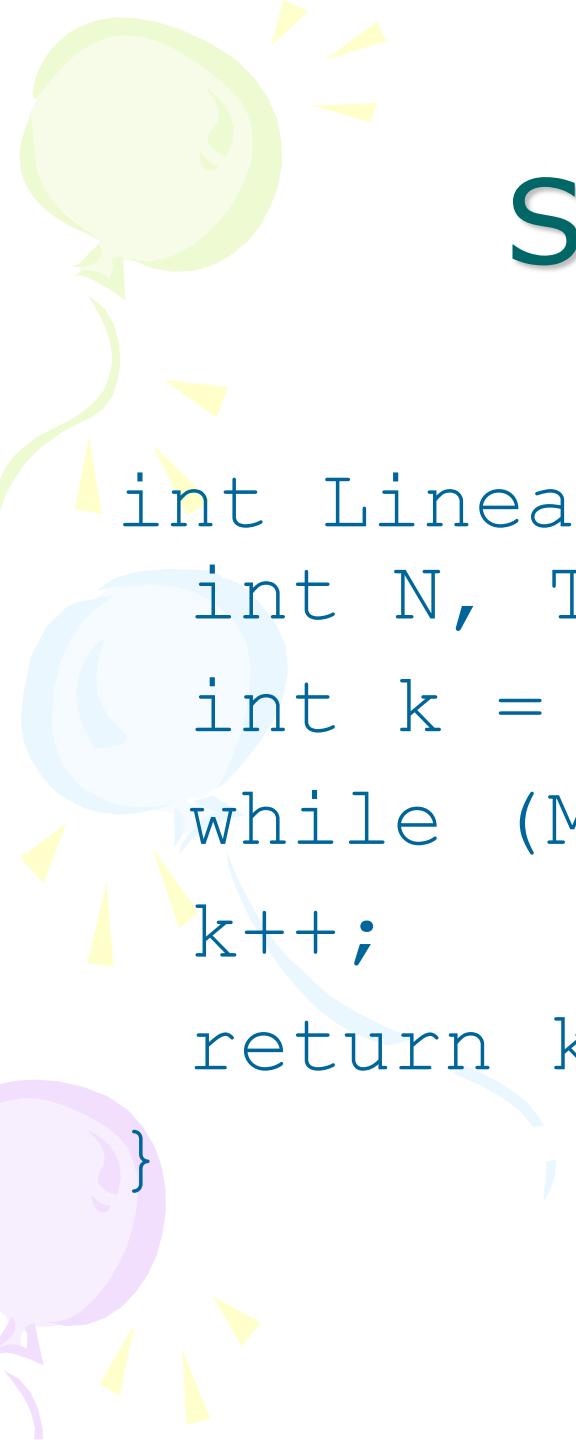
Sentinel

- Note that each iteration require two conditions to be checked and one statement to be executed.
- We can avoid checking for the end of the array on every iteration by inserting the target as an extra 'sentinel' element at the end of the array.
- We place it at position n and follow the algorithm:



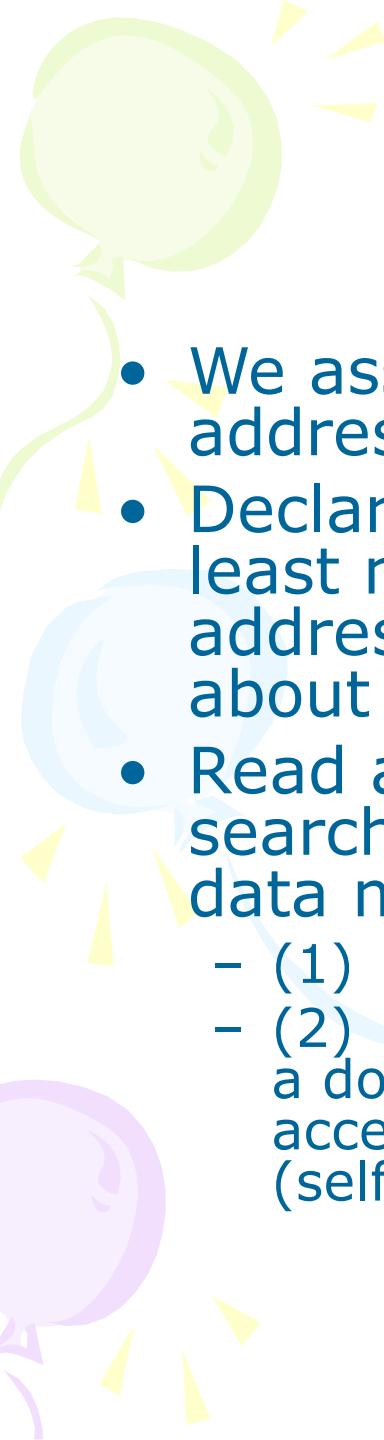
Sentinel

- Search sequentially from position 0 until the target is found (it will definitely be found).
- If the target is found in position n then the sentinel has been found – search has ‘failed’,
- else search was successful, return first index where target was found.



Sentinel search

```
int LinearSentinelSearch (T M[],  
int N, T X) {  
    int k = 0; M[N]=X;  
    while (M[k] != X)  
        k++;  
    return k-1;  
}
```

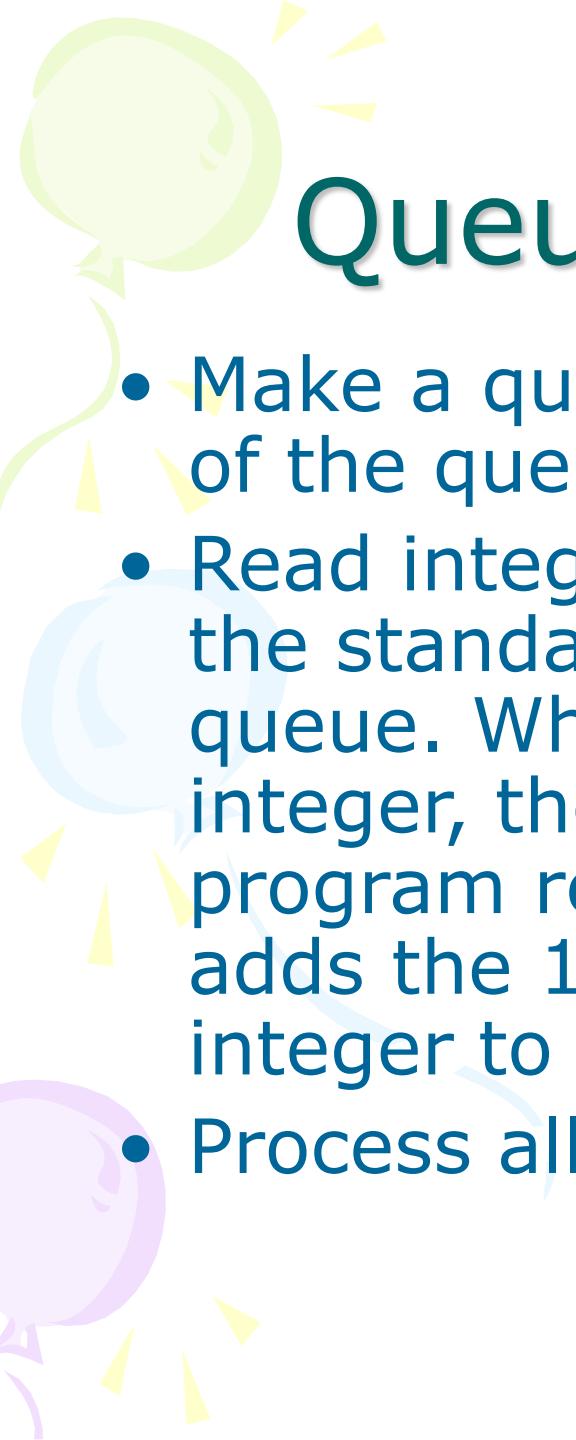


Exercise 6-1

- We assume that you write a mobile phone's address book.
- Declare a structure "Address" that can hold at least name, telephone number, and e-mail address, and write a program that can handle about 100 address data.
- Read about 10 address data from the input file, search a name by the linear search, and write the data matched first to the output file.
 - (1) Implement this program using an array of structure.
 - (2) Implement this program using a singly-linked list or a doubly-linked list. Confirm the second search is accelerated by moving data matched to the head of list (self-organizing search).

Exercise 6-2: Searching Arrays by Linear Search

- Read 11 integers from the standard input and assign first ten integers to the array.
- Then if the 11th integer is in the array, output the position of the element (1 - 10). If not, output 0.

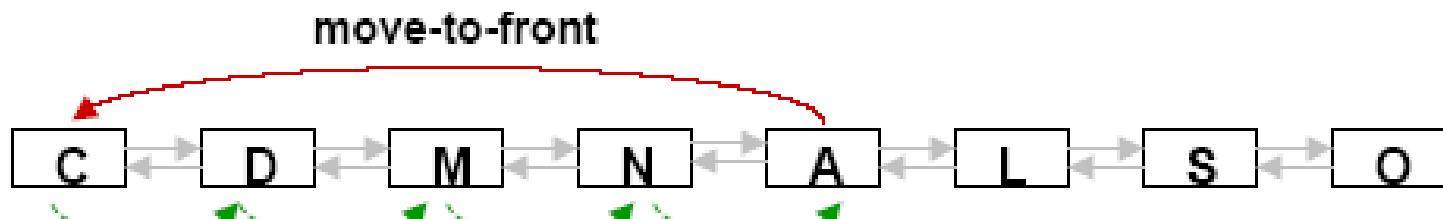


Queue (move to front)

- Make a queue that holds integers. The size of the queue is fixed to 10.
- Read integers separated by spaces from the standard input, and add them to the queue. When the program reads the 11th integer, the queue is already full. So the program removes the first integer and adds the 11th integer. Print the removed integer to the standard output.
- Process all the integers in this way.

Self organizing search (move to front)

- Any element searched/requested is moved to the front



Self organizing search (move to front)

```
int search( int key, int r[], int n )
{
    int i, j;
    int tempr;
    for ( i=0; i<n-1 && r[i] != key; i++ );
    if ( key == r[i] )
    { if ( i>0 ) {
        tempr = r[i];
        for (j=0, j<i; j++) r[j+1]=r[j];
        r[0]=tempr;
    };
    return( i );
} else return( -1 );
```

Self-organizing (Transpose) sequential search

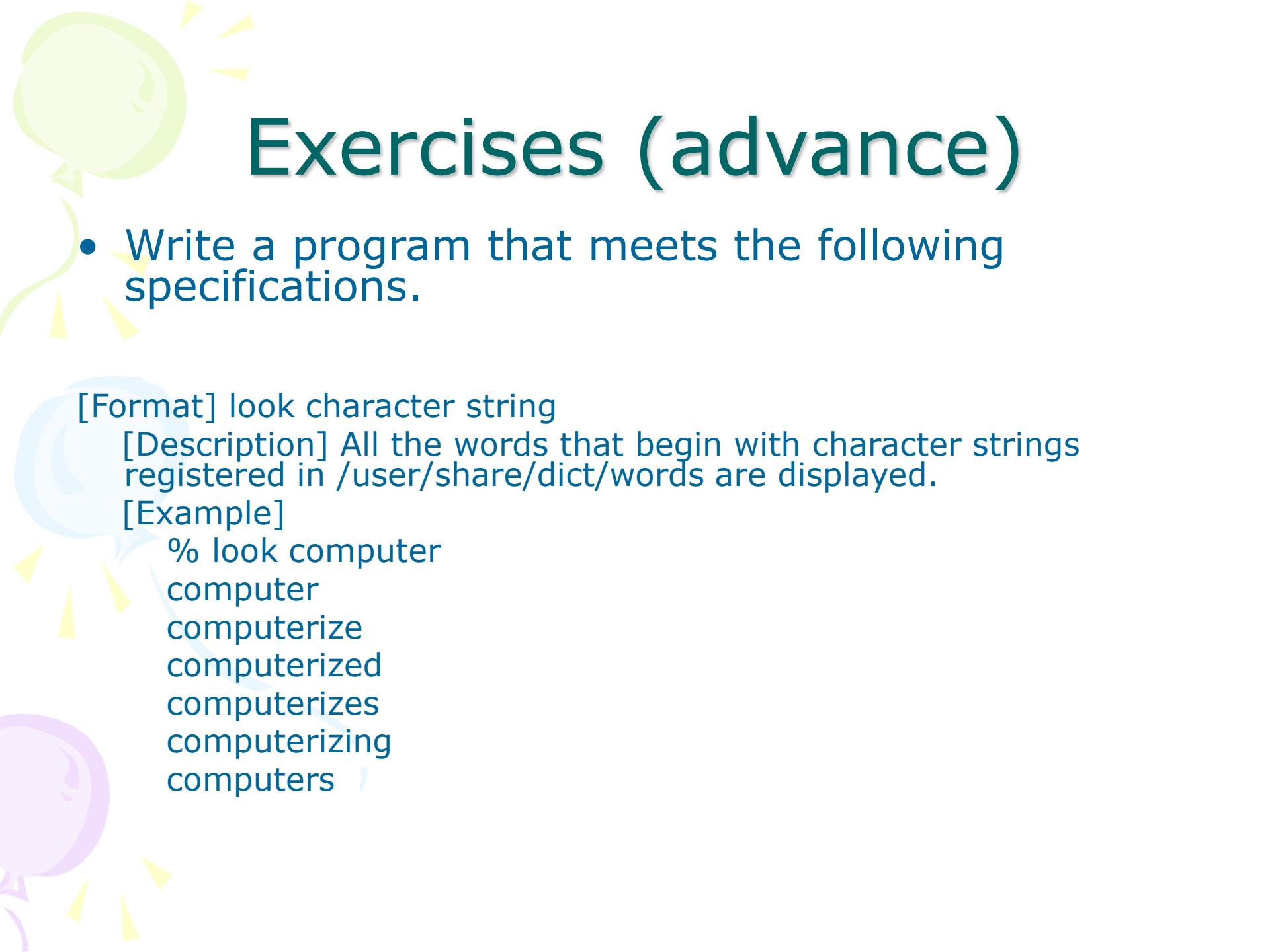
```
int search( int key, int r[], int n )
{
    int i;
    int tempr;
    for ( i=0; i<n-1 && r[i] != key; i++ );
    if ( key == r[i] )
    { if ( i>0 ) {
/** Transpose with predecessor **/
        tempr = r[i];
        r[i] = r[i-1];
        r[--i] = tempr;
    };
    return( i );
} else return( -1 );
```

Exercise: Self Organized List

- Modify a list that you have created in previous exercises which support the capacity of self-organizing using "move to front" strategy.
- Infact, develop the function search an element in a list.

Exercise: Self Organized List

- Implement a Self Organized List using Transpose strategy.



Exercises (advance)

- Write a program that meets the following specifications.

[Format] look character string

[Description] All the words that begin with character strings registered in /user/share/dict/words are displayed.

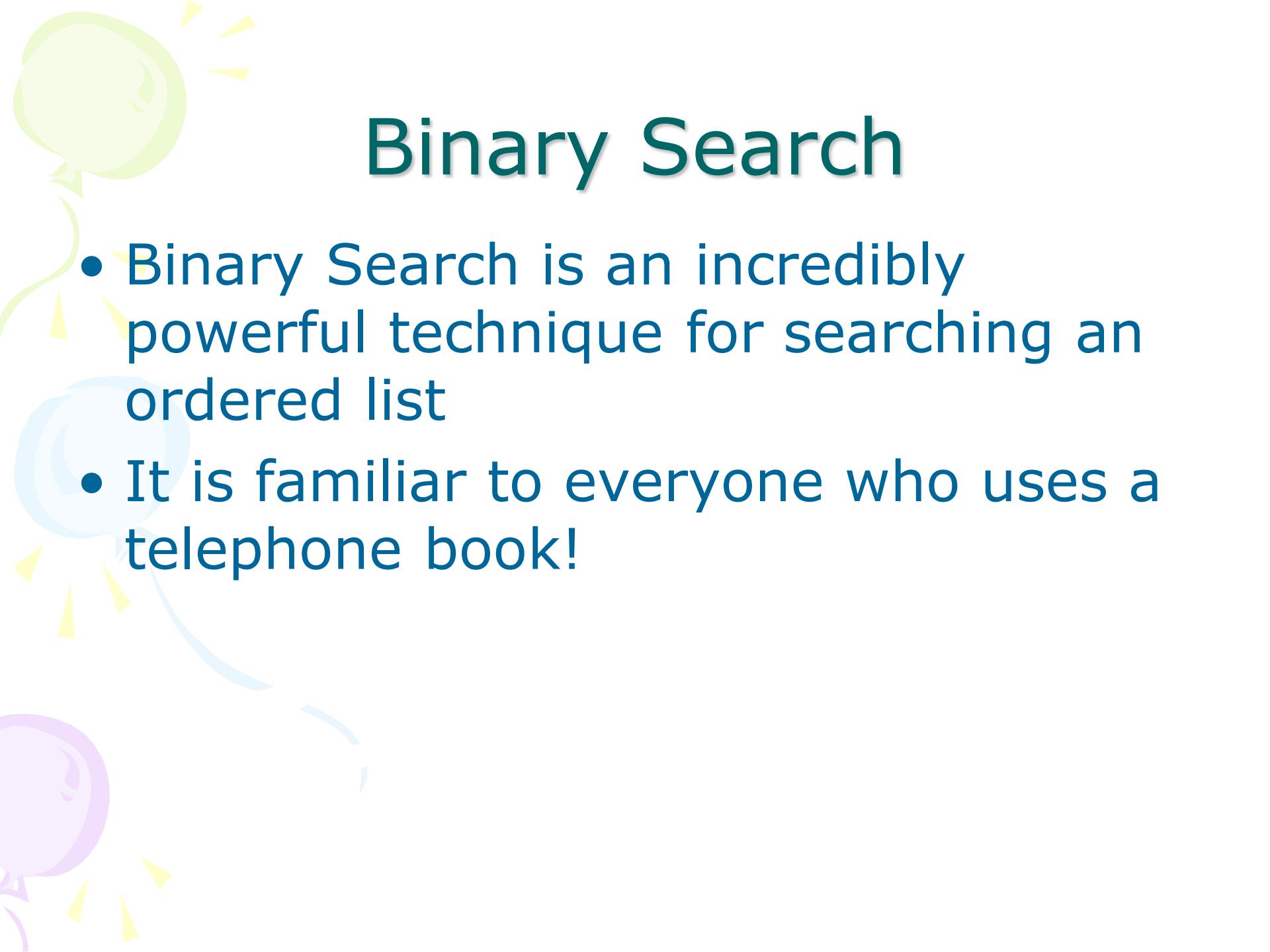
[Example]

```
% look computer  
computer  
computerize  
computerized  
computerizes  
computerizing  
computers
```

Binary Search

1	3	5	6	10	11	14	25	26	40	41	78
---	---	---	---	----	----	----	----	----	----	----	----

- The binary search algorithm uses a divide-and-conquer technique to search the list.
- First, the search item is compared with the middle element of the list.
- If the search item is less than the middle element of the list, restrict the search to the first half of the list.
- Otherwise, search the second half of the list.



Binary Search

- Binary Search is an incredibly powerful technique for searching an ordered list
- It is familiar to everyone who uses a telephone book!

Illustration

- Searching for a key=78

1	3	5	6	10	11	14	25	26	40	41	78
---	---	---	---	----	----	----	----	----	----	----	----

1	3	5	6	10	11	14	25	26	40	41	78
---	---	---	---	----	----	----	----	----	----	----	----

$$11 \leq 78$$

14	25	26	40	41	78
----	----	----	----	----	----

$$26 \leq 78$$

40	41	78
----	----	----

$$41 \leq 78$$

78

$$78 = 78$$

4 opérations necessary for finding out the good element.
How many operations in case of sequential search?

Example

- First, compare 75 with the middle element in this list, $L[6]$ (which is 39).
- Because $75 > L[6] = 39$, restrict the search to the list $L[7 \dots 12]$, as shown in Figure.

Binary Search Code

```
int binSearch(int List[], int Target, int Size) {  
    int Mid,  
        Lo = 0,  
        Hi = Size - 1;  
    while ( Lo <= Hi ) {  
        Mid = (Lo + Hi) / 2;  
        if ( List[Mid] == Target )  
            return Mid;  
        else if ( Target < List[Mid] )  
            Hi = Mid - 1;  
        else  
            Lo = Mid + 1;  
    }  
    return -1;  
}
```

Test Program

```
#include <stdio.h>
#define NotFound (-1)
typedef int ElementType;

int BinarySearch(ElementType A[ ], ElementType X, int N ) {
    int Low, Mid, High;
    Low = 0; High = N - 1;
    while( Low <= High ) {
        Mid = ( Low + High ) / 2;
        if( A[ Mid ] < X )
            Low = Mid + 1;
        elseif( A[ Mid ] > X )
            High = Mid - 1;
        else
            return Mid; /* Found */
    }
    return NotFound; /* NotFound is defined as -1 */
}

main( )
{
    static int A[ ] = { 1, 3, 5, 7, 9, 13, 15 };
    int SizeofA = sizeof( A ) / sizeof( A[ 0 ] );
    int i;
    for( i = 0; i < 20; i++ )
        printf( "BinarySearch of %d returns %d\n",
                i, BinarySearch( A, i, SizeofA ) );
    return 0;
}
```

Exercise: Recursive Binary Search

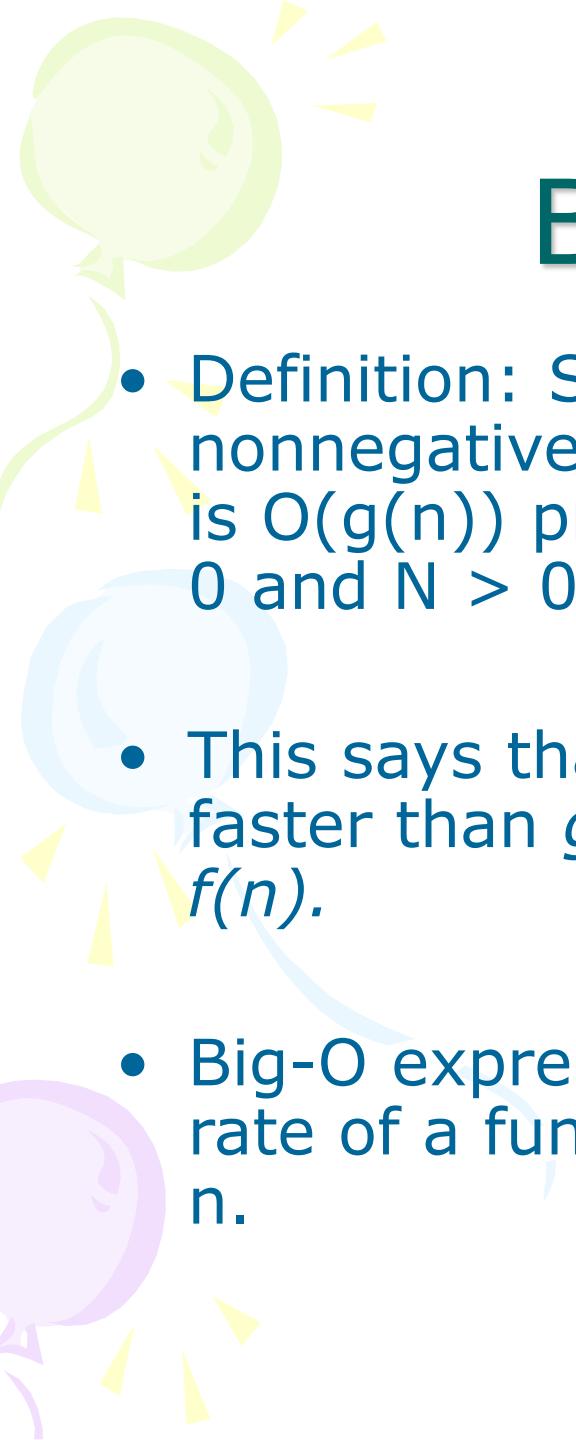
- Implement a recursive version of a binary search function.

Solution

```
#define NotFound (-1)
typedef int ElementType;

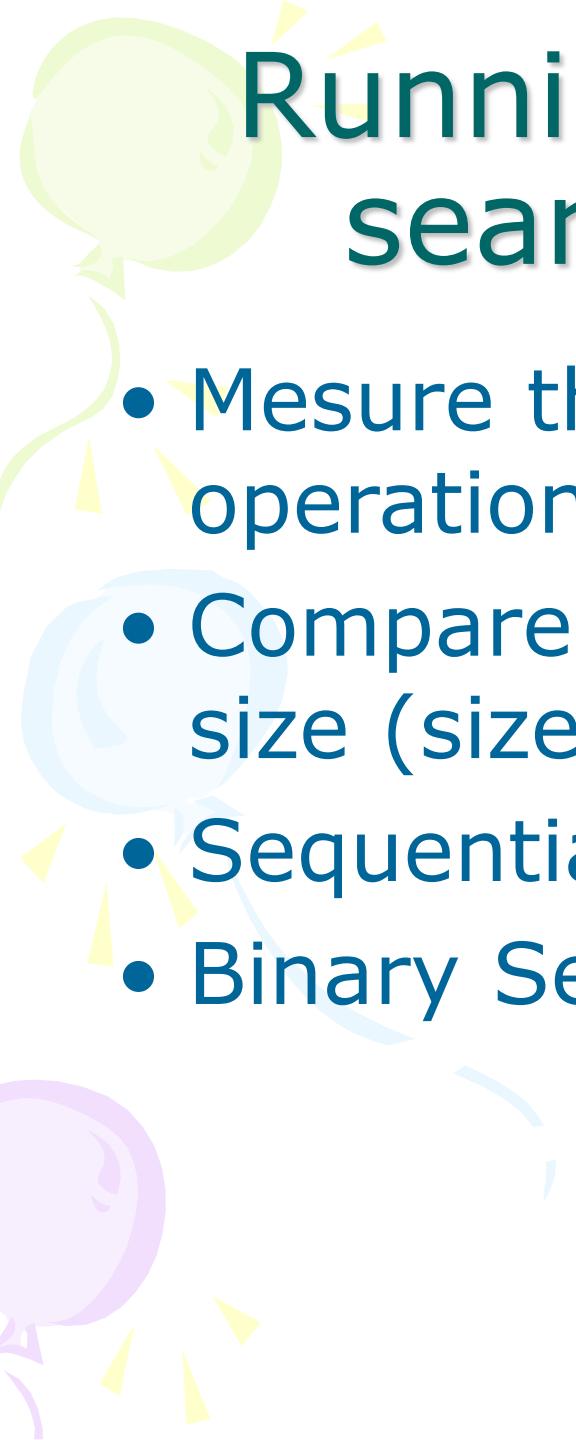
int BinarySearch(ElementType A[ ], ElementType X, int Lo, int
Hi ) {
    if (Lo > High) return NotFound;
    Mid = ( Low + High ) / 2;
    if (A[ Mid ] < X ) return BinarySearch(A, X, Mid+1, Hi);
    elseif ( A[ Mid ] > X )
        return BinarySearch(A, X, Lo, Mid - 1);
    else
        return Mid; /* Found */
}
return NotFound; /* NotFound is defined as -1 */
```

Usage: `BinarySearch(A, X, 0, size -1);`



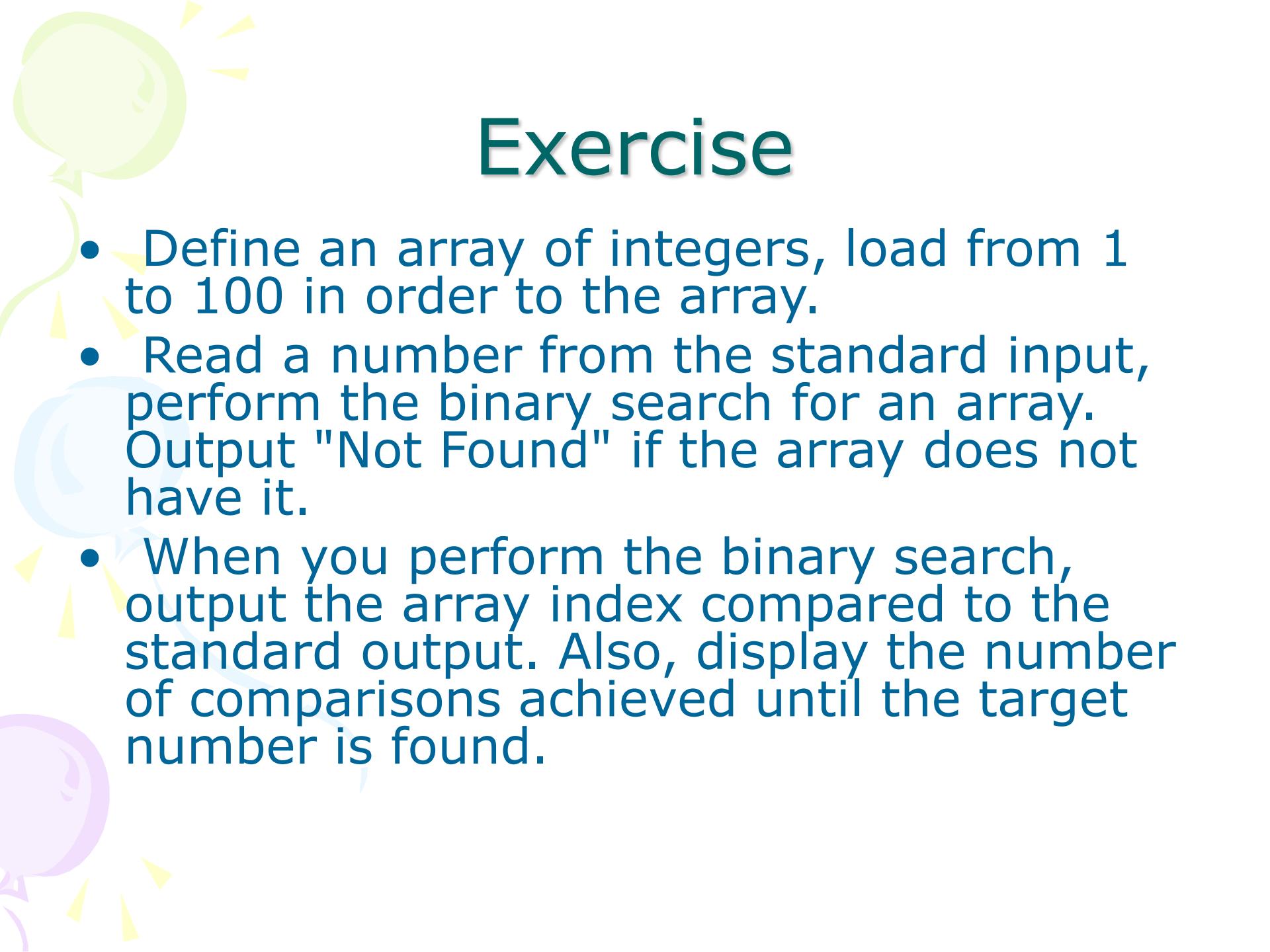
Big O Notation

- Definition: Suppose that $f(n)$ and $g(n)$ are nonnegative functions of n . Then we say that $f(n)$ is $O(g(n))$ provided that there are constants $C > 0$ and $N > 0$ such that for all $n > N$, $f(n) \leq Cg(n)$.
- This says that function $f(n)$ grows at a rate no faster than $g(n)$; thus $g(n)$ is an upper bound on $f(n)$.
- Big-O expresses an upper bound on the growth rate of a function, for sufficiently large values of n .



Running time analysis in searching algorithms

- Measure the number of comparison operations
- Compare results with the problem's size (size of input data)
- Sequential Search: $O(n)$
- Binary Search: $O(\log_2 n)$



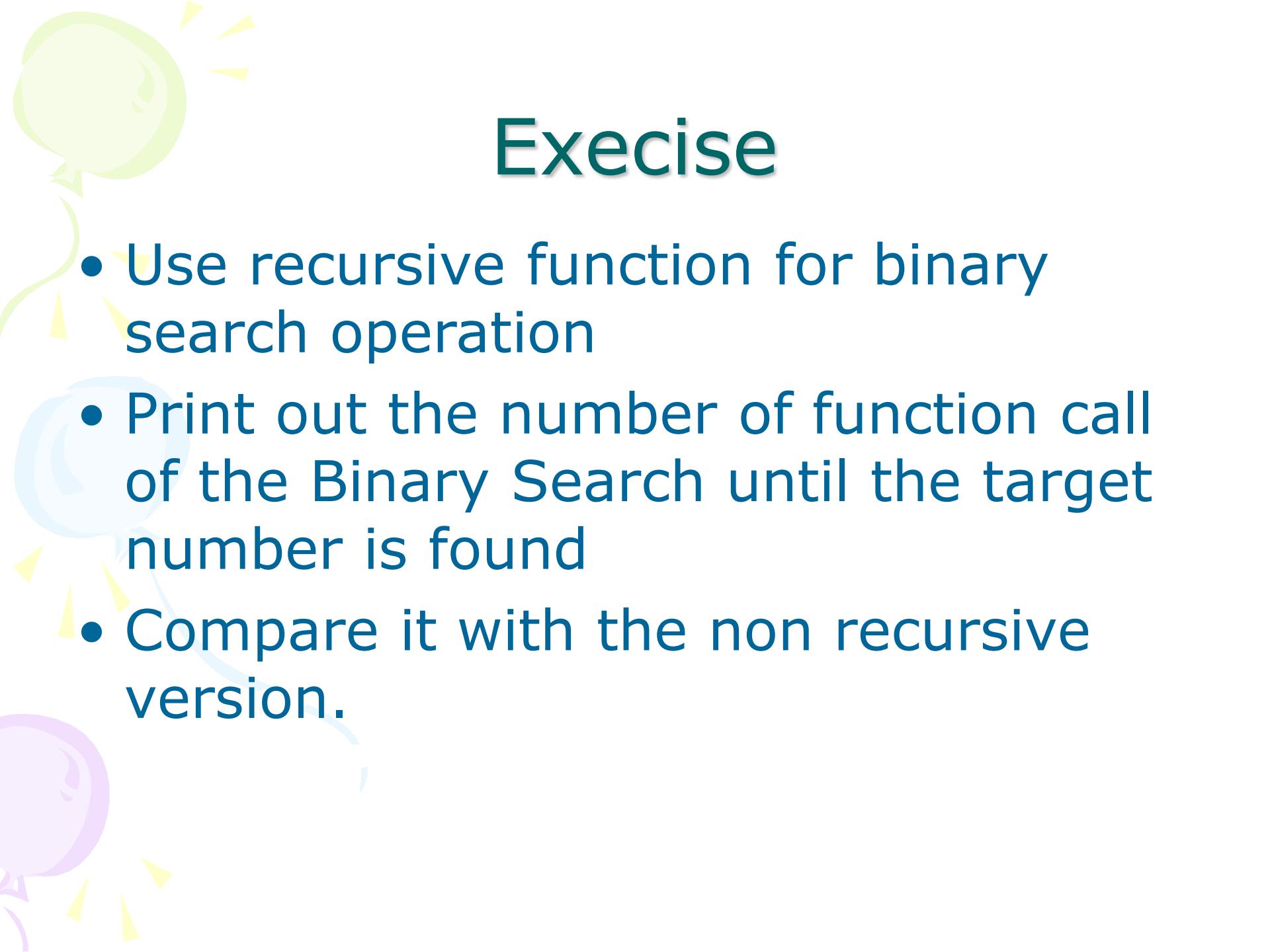
Exercise

- Define an array of integers, load from 1 to 100 in order to the array.
- Read a number from the standard input, perform the binary search for an array. Output "Not Found" if the array does not have it.
- When you perform the binary search, output the array index compared to the standard output. Also, display the number of comparisons achieved until the target number is found.



Hint

- With each comparison:
 - increment a global variable counter



Excise

- Use recursive function for binary search operation
- Print out the number of function call of the Binary Search until the target number is found
- Compare it with the non recursive version.

Dictionary Order and Binary Search

- When you search for a string value, the comparison between two values is based on dictionary order.
- We have:
 - 'a' < 'd', 'B' < 'M'
 - "acerbook" < "addition"
 - "Chu Trong Hien" > "Bui Minh Hai"
- Just use: `strcmp` function.



Exercise

- We assume that you make a mobile phone's address book.
- Declare the structure which can store at least "name", "telephone number", "e-mail address.". And declare an array of the structure that can handle about 100 address data.
- Read this array data of about 10 from an input file, and write a name which is equal to a specified name and whose array index is the smallest to an output file. Use the binary search for this exercise

Solution

```
#include <stdio.h>
#include <string.h>

enum { SUCCESS, FAIL, MAX_ELEMENT = 100 };

// the phone book structure
typedef struct phoneaddress_t {
    char name[20];
    char tel[11];
    char email[25];
} phoneaddress;
```

Solution: implement Dictionary order Binary Search

```
int BinarySearch(phoneaddress A[ ], char name[] , int N ) {  
    int Low, Mid, High;  
    Low = 0; High = N - 1;  
    while( Low <= High ) {  
        Mid = ( Low + High ) / 2;  
        if( strcmp(A[ Mid ].name, name) < 0 )  
            Low = Mid + 1;  
        else if(strcmp(A[ Mid ].name, name) > 0)  
            High = Mid - 1;  
        else  
            return Mid; /* Found */  
    }  
    return NotFound; /* NotFound is defined as -1 */  
}
```

Solution

```
int main(void)
{
    FILE *fp, fpout;
    phoneaddress phonearr[MAX_ELEMENT];
    int i,n, irc; // return code
    char name[20];
    int reval = SUCCESS

    printf("How many contacts do you want to enter
(<100)?"); scanf("%d", &n);
    if ((fp = fopen("phonebook.dat","rb")) == NULL) {
        printf("Can not open %s.\n", "phonebook.dat");
        reval = FAIL;
    }
    irc = fread(phonearr, sizeof(phoneaddress), n, fp);
    printf(" fread return code = %d\n", irc); fclose(fp);
    if (irc <0) {
        printf (" Can not read from file!");
        return -1;
    }
}
```

Solution (next)

```
printf("Let me know the name you want to search:");
gets(name);
irc = BinarySearch(phonearr, name,n);
if (irc <0) {
    printf (" No contact match the criteria!";
    return -1;
}
// write result to outputfile
if ((fpout = fopen("result.txt", "w")) == NULL) {
    printf("Can create file to write.\n");
    reval = FAIL;
}
else
    fprintf(fpout, "%s have the email address %s and
telephone number:%s", phonearr[i].name,
phonearr[i].email, phonearr[i].tel);
fclose(fpout);
return reval;
}
```

Exercise

- Return to SortedList exercise in Week4 (student management) (Linked List) with structure of an element:

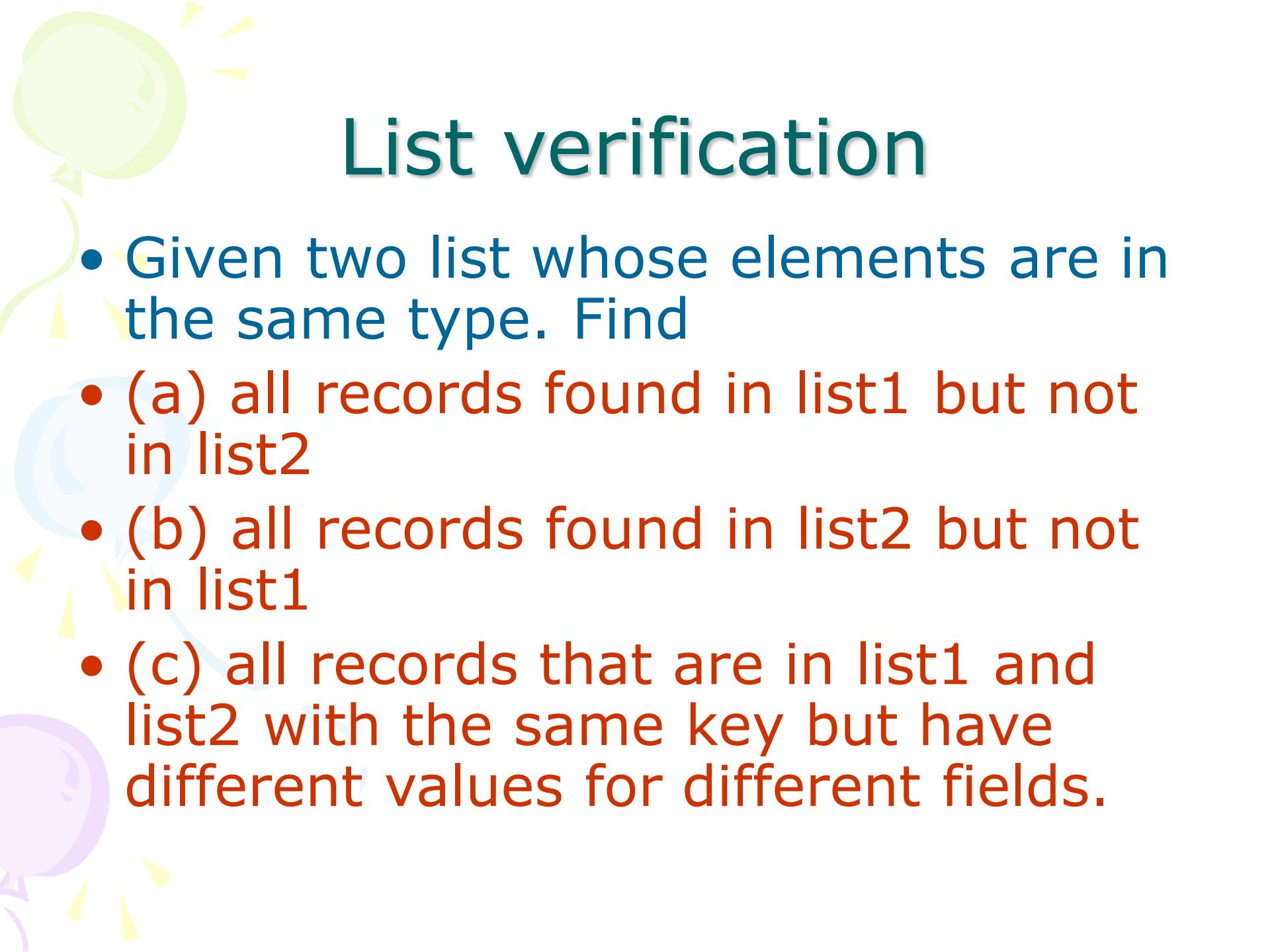
```
typedef struct Student_t {  
    char id[ID_LENGTH];  
    char name[NAME_LENGTH];  
    int grade;  
  
    struct Student_t *next;  
} Student;
```

implement the function BinarySearch for this list based on
- the name
- the grade
of students



List verification

- Compare lists to verify that they are identical or identify the discrepancies.
- example
 - international revenue service (e.g., employee vs. employer)
- complexities
 - random order: $O(mn)$
 - ordered list:
 $O(tsort(n)+tsort(m)+m+n)$

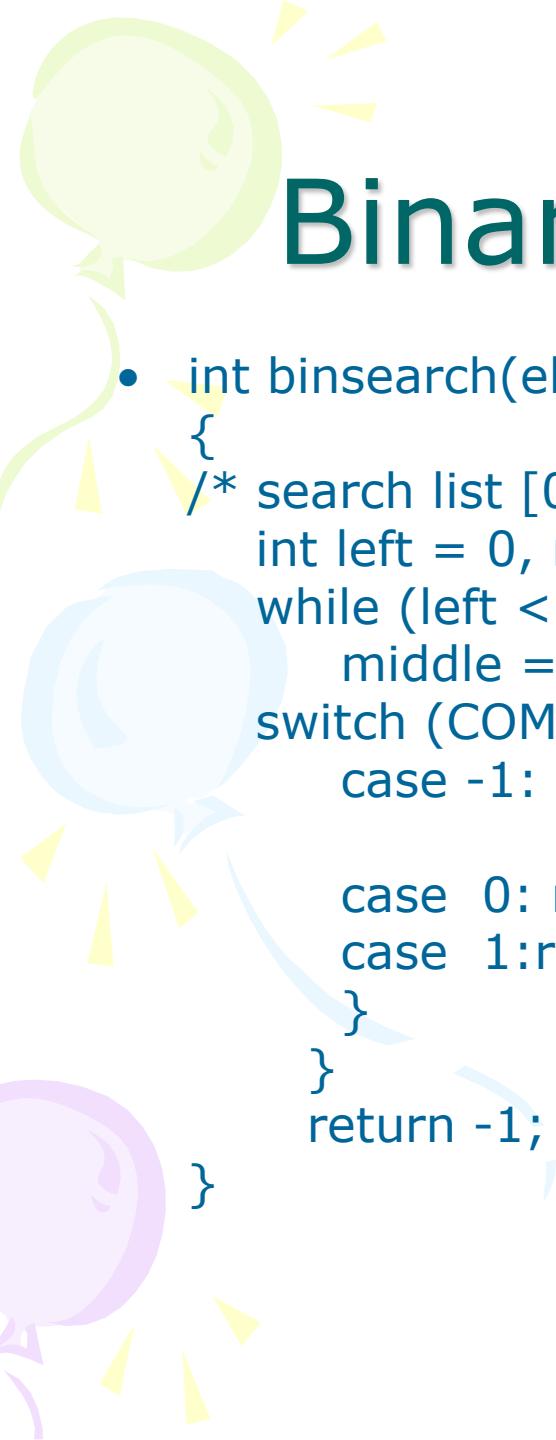


List verification

- Given two list whose elements are in the same type. Find
 - (a) all records found in list1 but not in list2
 - (b) all records found in list2 but not in list1
 - (c) all records that are in list1 and list2 with the same key but have different values for different fields.

Solution: Element type and List declaration

- ```
define MAX-SIZE 1000/* maximum size of list plus one */
typedef struct {
 int key;
 /* other fields */
} element;
element list[MAX_SIZE];
```



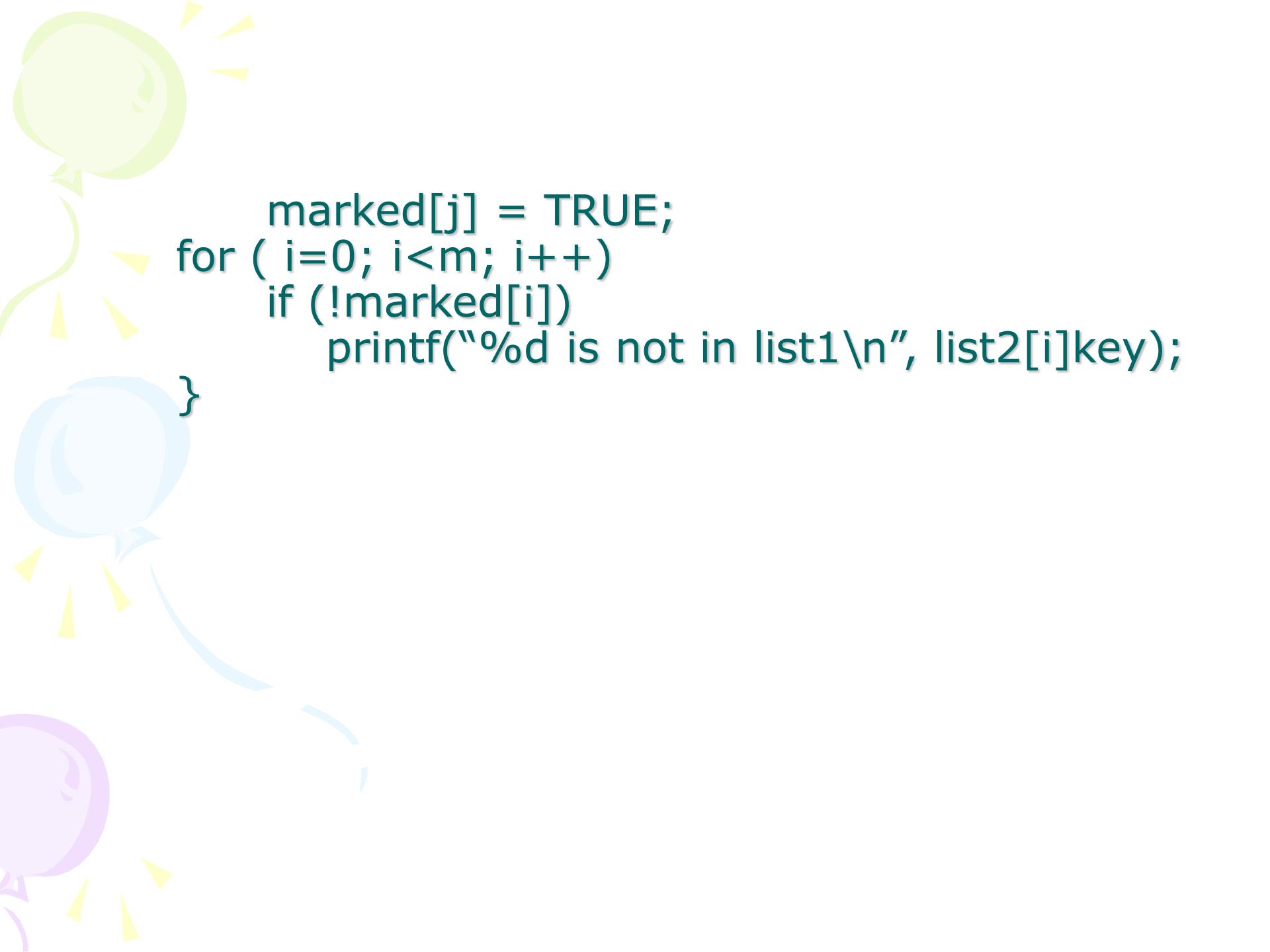
# Binary Search Function

- ```
int binsearch(element list[ ], int searchnum, int n)
{
    /* search list [0], ..., list[n-1]*/
    int left = 0, right = n-1, middle;
    while (left <= right) {
        middle = (left+ right)/2;
        switch (COMPARE(list[middle].key, searchnum)) {
            case -1: left = middle +1;
                        break;
            case 0: return middle;
            case 1:right = middle - 1;
        }
    }
    return -1;
}
```

verifying using a sequential search

```
void verify1(element list1[], element list2[ ], int n, int m)
/* compare two unordered lists list1 and list2 */
{
    int i, j;
    int marked[MAX_SIZE];

    for(i = 0; i<m; i++)
        marked[i] = FALSE;
    for (i=0; i<n; i++)
        if ((j = seqsearch(list2, m, list1[i].key)) < 0)
            printf("%d is not in list 2\n ", list1[i].key);
        else
            /* check each of the other fields from list1[i] and list2[j], and
            print out any discrepancies */
```



```
marked[j] = TRUE;  
for ( i=0; i<m; i++)  
    if (!marked[i])  
        printf("%d is not in list1\n", list2[i].key);  
}
```

verifying using a binary search

```
void verify2(element list1[ ], element list2 [ ], int n, int m)
/* Same task as verify1, but list1 and list2 are sorted */
{
    int i, j;
    sort(list1, n);
    sort(list2, m);
    i = j = 0;
    while (i < n && j < m)
        if (list1[i].key < list2[j].key) {
            printf ("%d is not in list 2 \n", list1[i].key);
            i++;
        }
        else if (list1[i].key == list2[j].key) {
            /* compare list1[i] and list2[j] on each of the other field
               and report any discrepancies */
            i++; j++;
        }
}
```

verifying using a binary search

```
else {  
    printf("%d is not in list 1\n", list2[j].key);  
    j++;  
}  
for(; i < n; i++)  
    printf ("%d is not in list 2\n", list1[i].key);  
for(; j < m; j++)  
    printf("%d is not in list 1\n", list2[j].key);  
}
```