ECE 220 Computer Systems & Programming

Lecture 13 – Problem Solving with Pointers and Arrays

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ECE ILLINOIS

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Exercise: implement a function that interchanges two rows of a 5x5 matrix. The functions takes three arguments: pointer to the matrix, row number x and row number y.

```
#define SIZE 5
void row_interchange(int matrix[SIZE][SIZE], int x, int y){

}
```

Note:

- 2D arrays
  - <type> <name> [<dim1>][<dim2>];
  - e.g., int matrix[5][5];

*multi-dimensional array is stored in row-major order

linear index = row x (width of row) + col

(i.e. matrix[3][2] = 3*5+2 = 17)

```c
#include <stdio.h>
#define SIZE 5
//function to interchange 2 rows (x,y) in a 5x5 matrix

int matrix_ptr(int *matrix, int x, int y);
int main()
{
        int i, j;
        int matrix[SIZE][SIZE];

        printf("Initial Matrix: \n");
        for(i=0;i<SIZE;i++)
        {
                for(j=0;j<SIZE;j++)
                {
                        matrix[i][j]= i*SIZE+j;
                        printf("%d ", matrix[i][j]);
                }
                printf("\n");
        }
        printf("New Matrix: \n");
        //int rc = matrix_change(matrix, 2, 4);
        int rc = matrix_ptr(&matrix[0][0], 2, 4);
        if (rc != 0){
                printf("exchange row index out of bound\n");
                return rc;
        }
```

main Function (continue..)

```
29          for(i=0;i<SIZE;i++)
30          {
31                  for(j=0;j<SIZE;j++)
32                  {
33                          printf("%d ", matrix[i][j]);
34                  }
35                  printf("\n");
36          }
37          return 0;
38  }
```

```
40  int matrix_ptr(int *matrix, int x, int y){
41          //if x and y is greater than 5 or less than 0, just exit and return 1
42          if((x>SIZE-1) || (y>SIZE-1) || (x<0) || (y<0))
43                  return 1;
44
45          int j,temp;
46          for(j=0;j<SIZE;j++){
47                  temp=matrix[x*SIZE+j];
48                  matrix[x*SIZE+j] = matrix[y*SIZE+j];
49                  matrix[y*SIZE+j] = temp;
50          }
51          return 0;
52  }
```

Function without pointer argument:

```
int matrix_change(int matrix[SIZE][SIZE], int x, int y);
```

```
int matrix_change(int matrix[SIZE][SIZE], int x, int y)
{
        //if x and y is greater than 5 or less than 0, just exit and return 1
        if((x>SIZE-1) || (y>SIZE-1) || (x<0) || (y<0))
                return 1;

        int j, temp=0;
        for(j=0;j<SIZE;j++)
        {
                temp = matrix[x][j];
                matrix[x][j] = matrix[y][j];
                matrix[y][j] = temp;
        }
        return 0;
}
```

Pointers & Array Recap

- Reverse an integer array: void array_reverse(int array[], int size);

10	30	50	70

Index: 0 1 2 3

10	30	50	70	90

Index: 0 1 2 3 4

```c
#include <stdio.h>
void array_reverse(int array[], int n);
void print_array(int array[], int n);

int main(){
        int n;

        printf("Enter the size of array: ");
        scanf("%d", &n);

        int array[n];
        int i;

        printf("Set each element for this array\n");
        for(i=0;i<n;i++){
                printf("Input number %d: ", i);
                scanf("%d", &array[i]);
        }

        printf("Array before reverse:\n");
        print_array(array, n);

        array_reverse(array, n);

        printf("Array after reverse:\n");
        print_array(array, n);

        return 0;
}
```

```
31  void array_reverse(int array[], int n){
32          int i, temp;
33
34          for(i=0;i<(n/2);i++){
35                  temp = array[i];
36                  array[i] = array[n-i-1];
37                  array[n-i-1] = temp;
38          }
39  }
40
41  void print_array(int array[], int n){
42          int i;
43          for(i=0;i<n;i++){
44                  printf("%d ", array[i]);
45          }
46          printf("\n");
47  }
```

How about reversing a string of unknown size? See the Text, page 445 (code on github)

Multi-dimensional Arrays Recap

int a [2][3];

	Column 1	Column 2	Column 3
Row 1	a[0][0]	a[0][1]	a[0][2]
Row 2	a[1][0]	a[1][1]	a[1][2]

In memory

	index
a[0][0]	0
a[0][1]	1
a[0][2]	2
a[1][0]	3
a[1][1]	4
a[1][2]	5

* multi-dimensional array is stored in **row-major** order

Exercise:

Implement a function that transpose an n x m matrix

```c
#include <stdio.h>
#define ROW 2
#define COL 5
void transpose2(int *in, int *out);
void transpose(int in[ROW][COL], int out[COL][ROW]);
void print_matrix(int *matrix, int row, int col);

int main(){

    int in_array[ROW][COL], out_array[COL][ROW];

    //Set in_array value
    int i,j;
        for(i=0;i<ROW;i++){
                for(j=0;j<COL;j++){
            in_array[i][j]=i*COL+j;
                }
    }
    //Print in_array value
    printf("Input Array: \n");
    print_matrix(&in_array[0][0], ROW, COL);
    //Perform transpose
    //transpose(in_array, out_array);
    transpose2(&in_array[0][0], &out_array[0][0]);
    //Print out_array value
    printf("Output Array: \n");
    print_matrix(&out_array[0][0], COL, ROW);
    return 0;
}
```

```
#define ROW 2
#define COL 5
void transpose2(int *in_matrix, int *out_matrix){
```

Solution:

```
41  void transpose2(int *in_array, int *out_array){
42
43      int i,j;
44          for(i=0;i<ROW;i++){
45                  for(j=0;j<COL;j++){
46              out_array[j*ROW+i] = in_array[i*COL+j];
47                  }
48      }
49  }
```

```
}
```

Exercise: implement a function that transpose an n x n matrix

```
#define ROW 2
#define COL 5
void transpose(int in_matrix[ROW][COL], int out_matrix[COL][ROW]){

Simpler Solution:
```

```
void transpose(int in_array[ROW][COL], int out_array[COL][ROW]){

    int i,j;
        for(i=0;i<ROW;i++){
                for(j=0;j<COL;j++){
            out_array[j][i] = in_array[i][j];
                }
    }
}
```

```
}
```

Print Function:

```
void print_matrix(int *matrix, int row, int col){
        int i,j;
        for(i=0;i<row;i++){
                for(j=0;j<col;j++){
                        printf("%d ", matrix[i*col+j]);
                }
                printf("\n");
        }
}
```

1. Pointer Array & Pointer to an Array

```
int a[4];
int b[5];
int *ptr_array[2];
ptr_array[0] = &a[0]; /* ptr_array[0] = a; */
ptr_array[1] = &b[0]; /* ptr_array[1] = b; */

or

int a[4];
int b[5];
int *ptr_array[2] = {a,b};
```

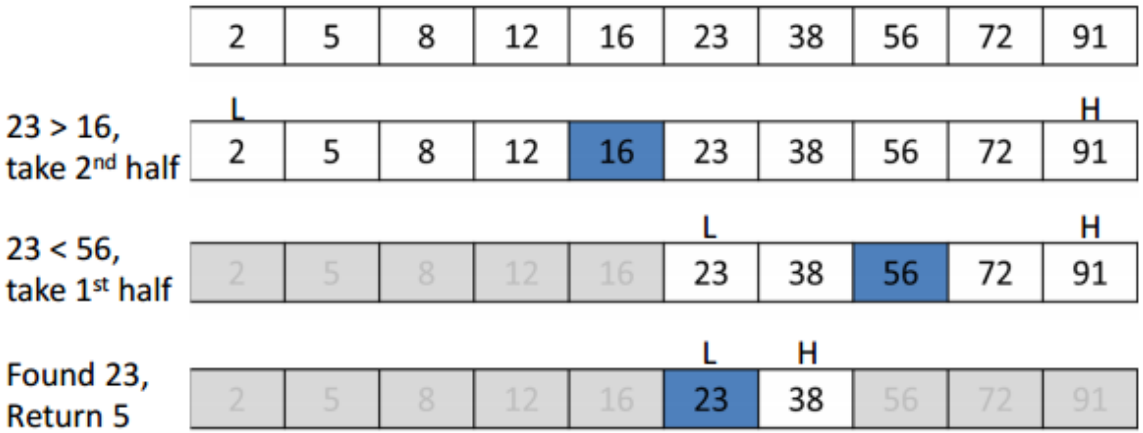
2. Search Algorithms

Linear Search: search from the beginning of the array until item is found

Binary Search: (for ***sorted*** array)

1) find the middle of the array and check if it's the search item;
2) search the first half if the search item is smaller than the center item, else search the second half;
3) repeat step 1 & 2 until search item is found.

If searching for 23 in the 10-element array:



Exercise: implement a function that performs binary search

This function takes two arguments: a pointer to the sorted array and the search item. If the search item is found, the function returns its index in the array. Otherwise, it returns -1.

```
#define SIZE 8
int binary_search(int array[], int item)
{




}
```

```c
#include <stdio.h>
#define LENGTH 8

int linearsearch(int array[], int item);
int binarysearch(int array[], int item);

int main()
{
    int array[LENGTH] = {2,3,5,6,8,9,10,13};

    //int idx = linearsearch(array, array[5]);
    int idx = binarysearch(array, array[5]);

    printf("item is found at index %d \n", idx);
    return 0;
}
//Simple Solution - not efficient:
int linearsearch(int array[], int item)
{
    int i;
    for(i=0;i<LENGTH;i++)
    {
        if(array[i] == item)
            return i;
    }

    return -1; //item not found
}
```

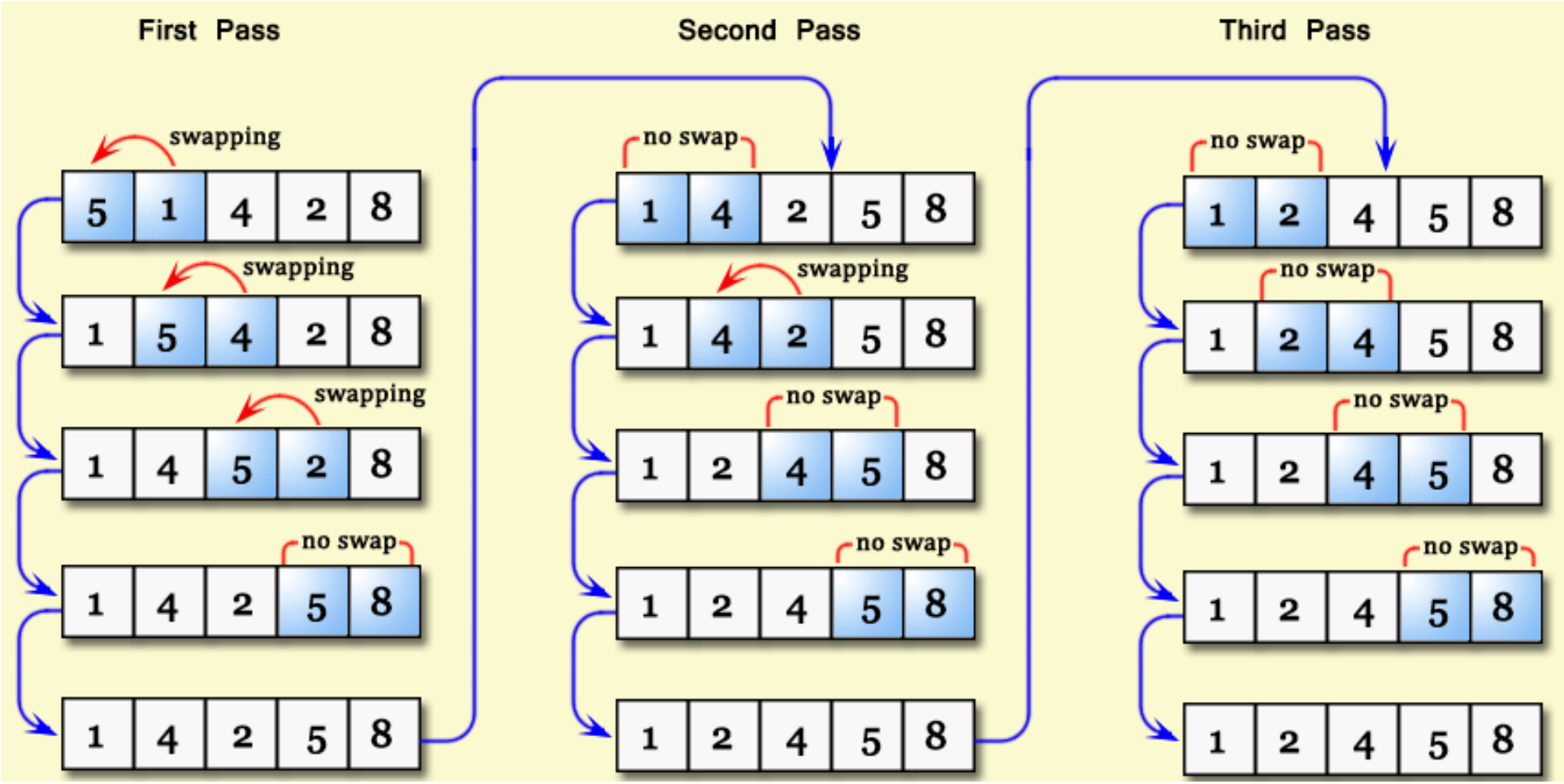
Exercise: implement a function that performs binary search

This function takes two arguments: a pointer to the sorted array and the search item. If the search item is found, the function returns its index in the array. Otherwise, it returns -1.

```
int binarysearch(int array[], int item)
{
    int n = LENGTH;
    int start=0, end=n-1;
    int middle;

    while(start <= end){
        middle = (start+end)/2;
        if(array[middle] == item){
            return middle;
        }
        else if(array[middle] > item){
            //search lower half if middle value greater than search item
            end = middle-1;
        }
        else{
            //search upper half if middle value smaller than search item
            start = middle+1;
        }
    }

    return -1; //item not found
}
```

3. Sorting Algorithms (bubble_sort)

Bubble Sort: 1) compare items next to each other and swap them if needed;
2) repeat this process until the entire array is sorted.



3. Sorting Algorithms (bubble_sort animation)

Bubble Sort: 1) compare items next to each other and swap them if needed;
2) repeat this process until the entire array is sorted.

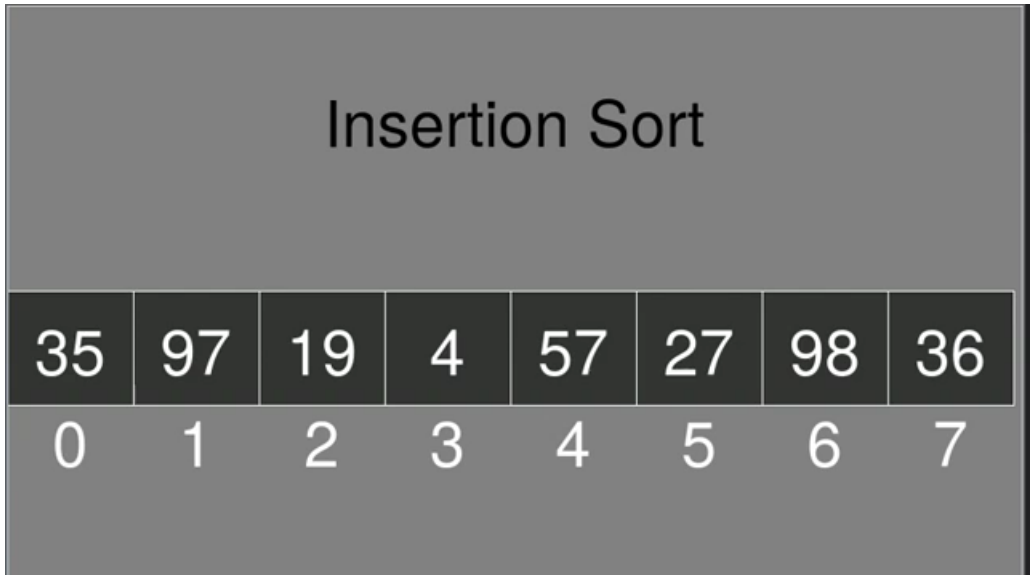
6 5 3 1 8 7 2 4

Exercise: implement a function that performs bubble sort

```c
#include <stdio.h>
#define SIZE 8

int main()
{
    int n = SIZE-1;
    int array[] = {6,5,3,1,8,7,2,4};

    int i, temp, swap = 0;

    //sort number in ascending order
    do
    {
        swap = 0;
        for(i=0;i<n;i++)
        {
            //swap the two numbers if order is incorrect
            if(array[i]>array[i+1])
            {
                temp = array[i];
                array[i] = array[i+1];
                array[i+1] = temp;
                //set the swap flag
                swap = 1;
            }
        }
        n--;
    }while(swap != 0);

    printf("sorted array: \n");
    for(i=0;i<SIZE;i++){
        printf("%d ", array[i]);
    }
    printf("\n");

    return 0;
}
```

4. Sorting Algorithms (Insertion Sort animation)

Bubble Sort: 1) compare pairs to the left and swap them if needed;
2) repeat this process until the entire array is sorted.



Exercise: implement a function that performs insertion sort

```c
#include <stdio.h>
#define SIZE 7
int main()
{
    int array[] = {35,97,19,4,57,27,36};

    //sort array in ascending order
    int i, j, temp
        for(i=1;i<SIZE;i++)
    {
        temp = array[i];
        for(j=i-1;j>=0;j--)
        {
            if(temp < array[j])
            {
                //shift element to the right
                array[j+1] = array[j];
                //update empty position
                //(i.e. swap)
                array[j] = temp;
            }
        }

    }
```

```c
    printf("sorted array: \n");
    for(i=0;i<SIZE;i++){
        printf("%d ", array[i]);
    }
    printf("\n");

    return 0;
}
```

Merge_Insertion Sort:

1) remove item from array, insert it at the proper location in the sorted part by shifting other items;
2) repeat this process until the end of array is reach.

6 5 3 1 8 7 2 4

Exercise: implement a function that performs insertion sort

```c
#include <stdio.h>
#define SIZE 8
int main()
{
    int array[] = {6,5,3,1,8,7,2,4};

    //sort array in ascending order
    int i, j, temp, empty = 0;
        for(i=1;i<SIZE;i++)
    {
        temp = array[i];
        for(j=i-1;j>=0;j--)
        {
            if(temp < array[j])
            {
                //shift element to the right
                array[j+1] = array[j];
                //update empty position
                empty = j;
            }
        }
        //insert at the proper location
        array[empty] = temp;
    }

    printf("sorted array: \n");
    for(i=0;i<SIZE;i++){
        printf("%d ", array[i]);
    }
    printf("\n");

    return 0;
}
```