



HA NOI UNIVERSITY OF SCIENCE AND TECHNOLOGY
SCHOOL OF INFORMATION AND COMMUNICATION TECHNOLOGY

C Programming Basic

Sorting – part II

Topics of this week

- Advanced Sorting Algorithm
 - Quick sort
 - Merge sort
- Exercises

Quicksort Algorithm

Given an array of n (e.g., integers):

- If array only contains one element, return
- Else
 - pick one element to use as *pivot*.
 - Partition elements into two sub-arrays:
 - Elements less than or equal to pivot
 - Elements greater than pivot
 - Quicksort two sub-arrays
 - Return results

Example

- We are given array of n integers to sort:

40	20	10	80	60	50	7	30	100
----	----	----	----	----	----	---	----	-----

Quick Sort

- Given $(R_0, R_1, \dots, R_{n-1})$
 K_i : pivot key
 if K_i is placed in $S(i)$,
 then $K_j \leq K_{S(i)}$ for $j < S(i)$,
 $K_j \geq K_{S(i)}$ for $j > S(i)$.
- $R_0, \dots, R_{S(i)-1}, R_{S(i)}, R_{S(i)+1}, \dots, R_{S(n-1)}$

two partitions

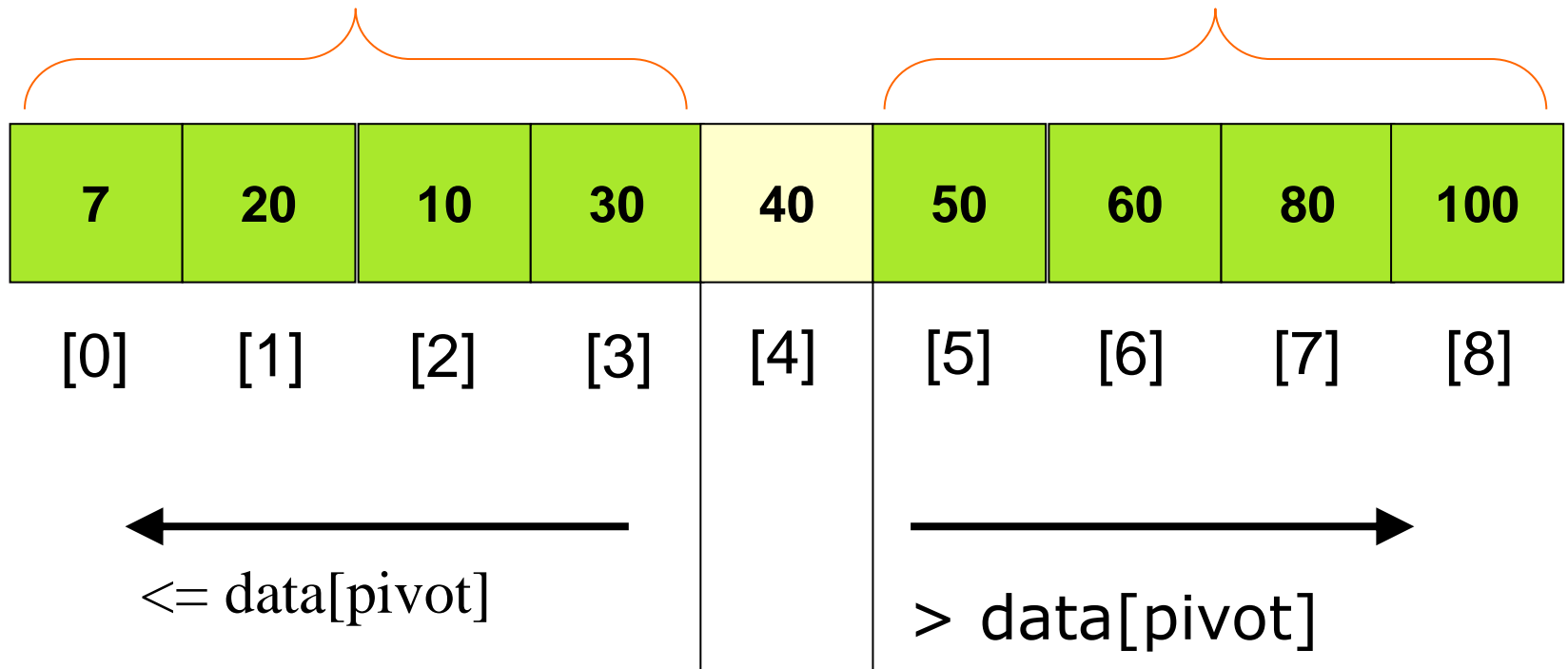
Partitioning Array

- Given a pivot, partition the elements of the array such that the resulting array consists of:
 1. One sub-array that contains elements \geq pivot
 2. Another sub-array that contains elements $<$ pivot
- The sub-arrays are stored in the original data array.
- Partitioning loops through, swapping elements below/above pivot.

Partition Result

7	20	10	30	40	50	60	80	100
[0]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
← ≤ data[pivot]					→ > data[pivot]			

Recursion: Quicksort Subarrays



Example for Quick Sort

R0	R1	R2	R3	R4	R5	R6	R7	R8	R9	left	right
{ 26	5	37	1	61	11	59	15	48	19}	0	9
{ 11	5	19	1	15}	26	{ 59	61	48	37}	0	4
{ 1	5}	11	{ 19	15}	26	{ 59	61	48	37}	0	1
1	5	11	15	19	26	{ 59	61	48	37}	3	4
1	5	11	15	19	26	{ 48	37}	59	{ 61}	6	9
1	5	11	15	19	26	37	48	59	{ 61}	6	7
1	5	11	15	19	26	37	48	59	61	9	9
1	5	11	15	19	26	37	48	59	61		

Quick Sort

```
void quicksort(element list[], int left, int right) {
    int pivot, i, j;
    element temp;
    if (left < right) {
        i = left;      j = right+1;
        pivot = list[left].key;
        do {
            do i++; while (i<=right &&
                           list[i].key < pivot);
            do j--; while (j>=left &&
                           list[j].key > pivot);
            if (i < j) SWAP(&list[i],&list[j]);
        } while (i < j);
        SWAP(&list[left], &list[j]);
        quicksort(list, left, j-1);
        quicksort(list, j+1, right);
    }
}
```

Exercise 11-1: Quick sort

- We assume that you make a mobile phone's address book.
- At the very least, you should declare the structure that can store "name", "phone number" and "e-mail address". And, you should declare the array that can store about 100 data that have this structure.
- Write a program that reads about 10 data from an input file to the array and writes the data to an output file after sorting in ascending order for name.
- You must use Quick sort for sorting.

Exercise 11-2

- Initiate an array of n random integers. n is entered by user.
- Sort the array with the insertion sort
- And using quicksort
- Compare the execution time of two algorithms.
- Run the program with various values of n to view the effect.

Exercise 11-3 Combination of quick sort and insertion sort

- When a program sorts a little number of the data, a program using insertion sort is faster than a program using quick sort and so on. So, a program sorts efficiently, if a program changes sorting algorithms by the number of data.
- You write a function that selects sorting algorithms – If number of the data is more than x numbers, the function selects quick sort. If not so, it selects insertion sort.
- Note: get the number “x” as the program argument.
- Read the text file that has more than 100 characters, sort the first 100 characters, and show the result by standard output.

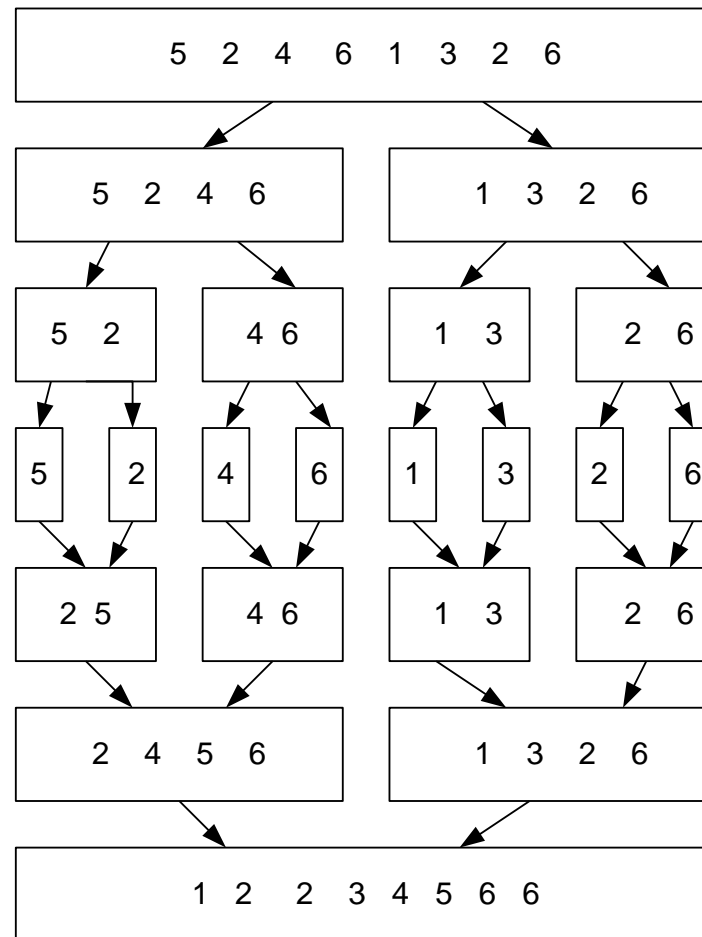
Merge Sort

- Problem: Given n elements, sort elements into non-decreasing order
- Apply divide-and-conquer to sorting problem
 - If $n=1$ terminate (every one-element list is already sorted)
 - If $n>1$, partition elements into two sub-arrays; sort each; combine into a single sorted array

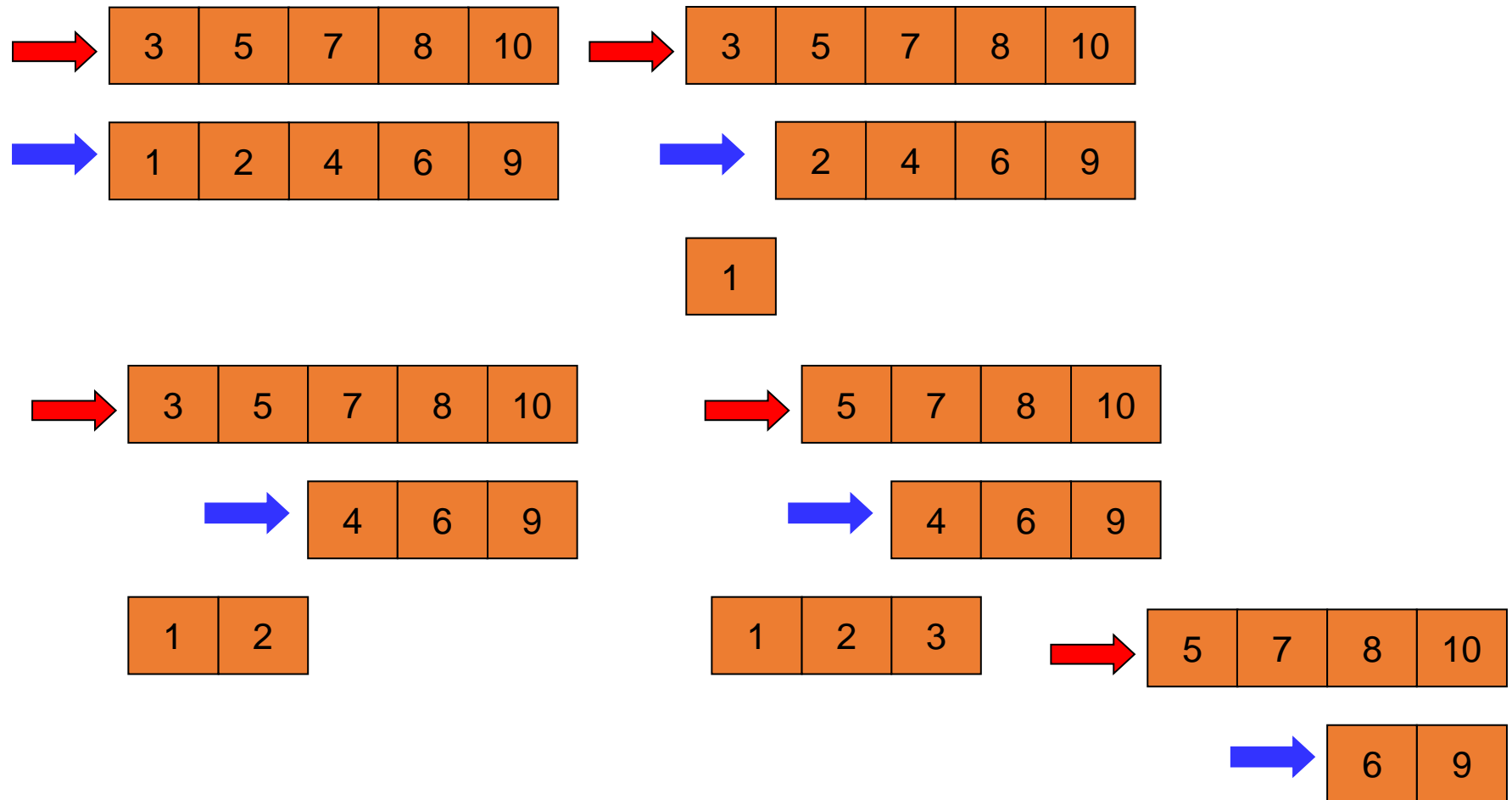
Algorithm

```
MergeSort (E[ 0 .. N])  
  if N < threshold  
    InsertionSort ( E[0..N] )  
  else  
    copy E[0.. N/2] to U[0.. N/2]  
    copy E[N/2 .. N] to V[0 .. N-N/2]  
    MergeSort(U[0 .. N/2])  
    MergeSort(V[0 .. N-N/2])  
    Merge( U[0 .. N/2], V[0 .. N-N/2}, E[0 .. N] )
```

Merge Sort: Example



Process of merge



Merge algorithm

```
Merge(U[0..m],V[0..n],E[0..n+m])  
  i = 0, j = 0, k = 0  
  while i<n && j<m  
    if U[i] < V [j]  
      E[k++] = U[i++]  
    else  
      E[k++] = V[j++]  
  while i<n E[k++] = U[i++]  
  while j<m E[k++] = V[j++]
```

Merge sort Implementation

```
void mergeSort(int arr[], int left, int right)
{
    if (left < right)
    {
        int mid = left + (right - left)/2;
        mergeSort(arr, left, mid);
        mergeSort(arr, mid + 1, right);
        merge(arr, left, mid, right);
    }
}
```

```
// Merge 2 subarray into arr[].
// First subarray is arr[left..mid]
// Second subarray is arr[mid+1..right]
void merge(int arr[], int left, int mid, int right)
{
    int i, j, k;
    int n1 = mid - left + 1;
    int n2 = right - mid;
    /* create temporary subarrays and copy data to them*/
    int Left_Arr[n1], Right_Arr[n2];
    for (i = 0; i < n1; i++)
        Left_Arr[i] = arr[left + i];
    for (j = 0; j < n2; j++)
        Right_Arr[j] = arr[mid + 1 + j];
```

```
/* Merge data from temporary sub array into original array  
arr[left..right]*/
```

```
    i = 0;
```

```
    j = 0;
```

```
    k = 1;
```

```
    while (i < n1 && j < n2) {
```

```
        if (Left_Arr[i] <= Right_Arr[j]) {
```

```
            arr[k] = Left_Arr[i];
```

```
            i++;
```

```
        }
```

```
        else{
```

```
            arr[k] = Right_Arr[j];
```

```
            j++;
```

```
        }
```

```
        k++;
```

```
    }
```

```
/* Copy the remaining member of Left_Arr[], if there are any */
while (i < n1) {
    arr[k] = Left_Arr[i];
    i++;
    k++;
}

/* Copy the remaining member of Right_Arr[], if there are any */
while (j < n2) {
    arr[k] = Right_Arr[j];
    j++;
    k++;
}
}
```

Exercise: 11-3 Merge sort

- We assume that you make a mobile phone's address book.
- At the very least, you should declare the structure that can store “name”, “phone number” and “e-mail address”. And, you should declare the singly-linked list that can store about 100 data that have this structure.
- Write a program that reads about 10 data from an input file to the list and writes the data to an output file after sorting in ascending order for name.
- You must use Merge sort for sorting.

Hints

- You can write a program that processes in the following order.
 - 1. Declare `char data[10]`.
 - 2. Read every 1 word from the standard input by `fgetc()` function and load it on the array “data”.
 - 3. Do the insertion sort to the array “data”
 - 4. Output every 1 word of the value of the sorted array “sort” by `fputc()` function.

Exercise 11-4: String sorting

- Write a program that sorts strings with quick sort by alphabetical order based on the following instructions.

I. Compare the character strings

- Write the function “preceding()” to search which of two character strings comes before by alphabetical order.

```
int preceding(char *first, char *second)
```

- A return value is by alphabetical order
 - Case that the character string of the argument “first” is before the character string of the argument “second” : 1
 - Case that the character string of the argument “first” is equal to the character string of the argument “second” : 0
 - Case that the character string of the argument “first” is after the character string of the argument “second” : -1

II. Input the character string from the file

- Write the function “setup_nameList()” to read the name of more than 2 persons and less than 25 persons from the file and set them to the array “nameList[]” of a character string (in fact, the array of the pointer to the character string)

```
int setup_nameList(char *namelist[], char *filename)
```

III. Implement Quicksort

- Write the function “qsort_name()” to sort the character string of the array “namelist[]” by alphabetical order with quick sort using the function you made ever.