# Data structure and algorithms lab

## SORTING II

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# Topics of this week

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

# Quicksort Algorithm

Given an array of *n* elements (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:

# Quick Sort (Hoare)

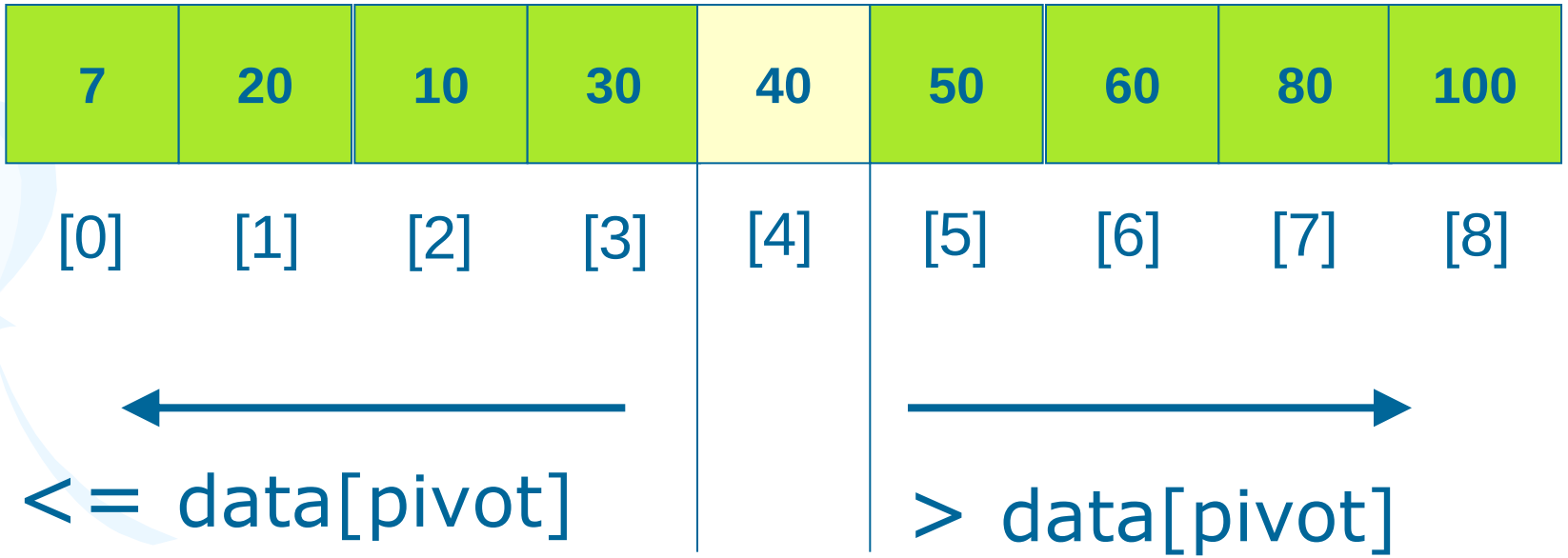
- Given $(R_0, R_1, \ldots, R_{n-1})$
  $K_i$: pivot key
  if $K_i$ is placed in S(i),
  then $K_j \le K_{s(i)}$ for $j < S(i)$,
  $K_j \ge K_{s(i)}$ for $j > S(i)$.
- $R_0, \ldots, R_{S(i)-1}, R_{S(i)}, R_{S(i)+1}, \ldots, R_{S(n-1)}$

two partitions

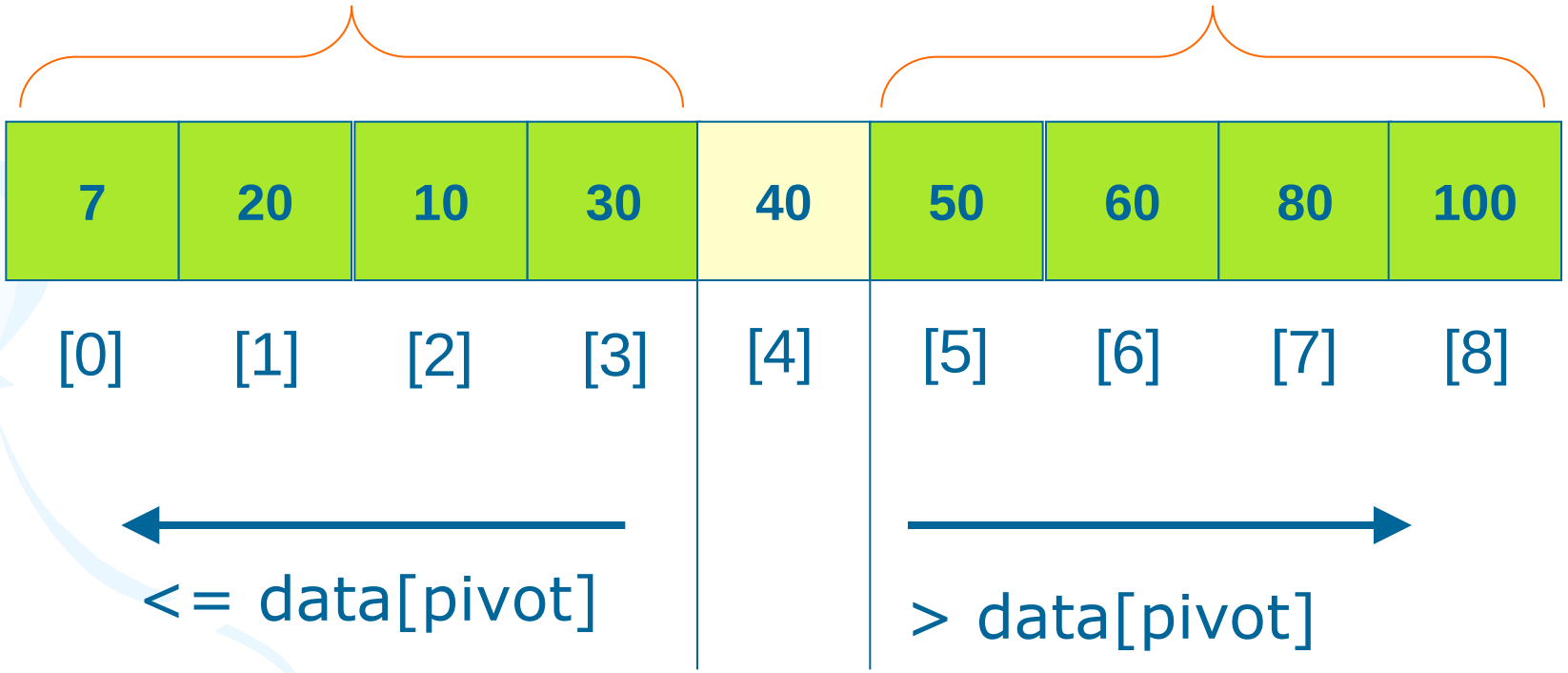
# Partitioning Array

- Given a pivot, partition the elements of the array such that the resulting array consists of:
- 1. One sub-array that contains elements >= 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



# 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 (list[i].key < pivot);
         do j--; while (list[j].key > pivot);
         if (i < j) SWAP(list[i], list[j], temp);
      } while (i < j);
      SWAP(list[left], list[j], temp);
      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.
- You 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.

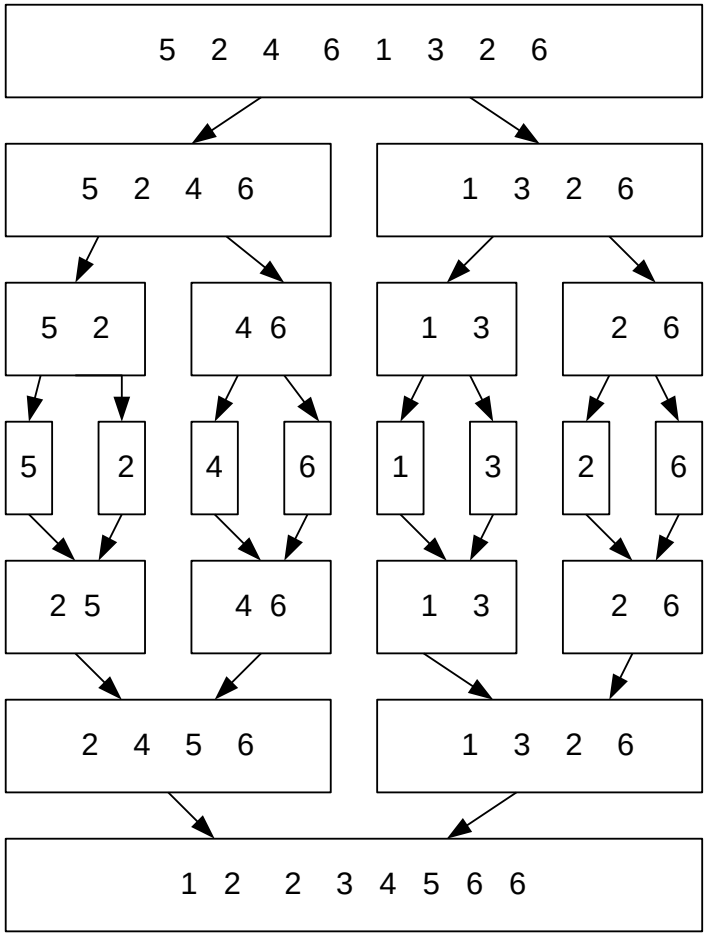
# Merge Sort

- 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

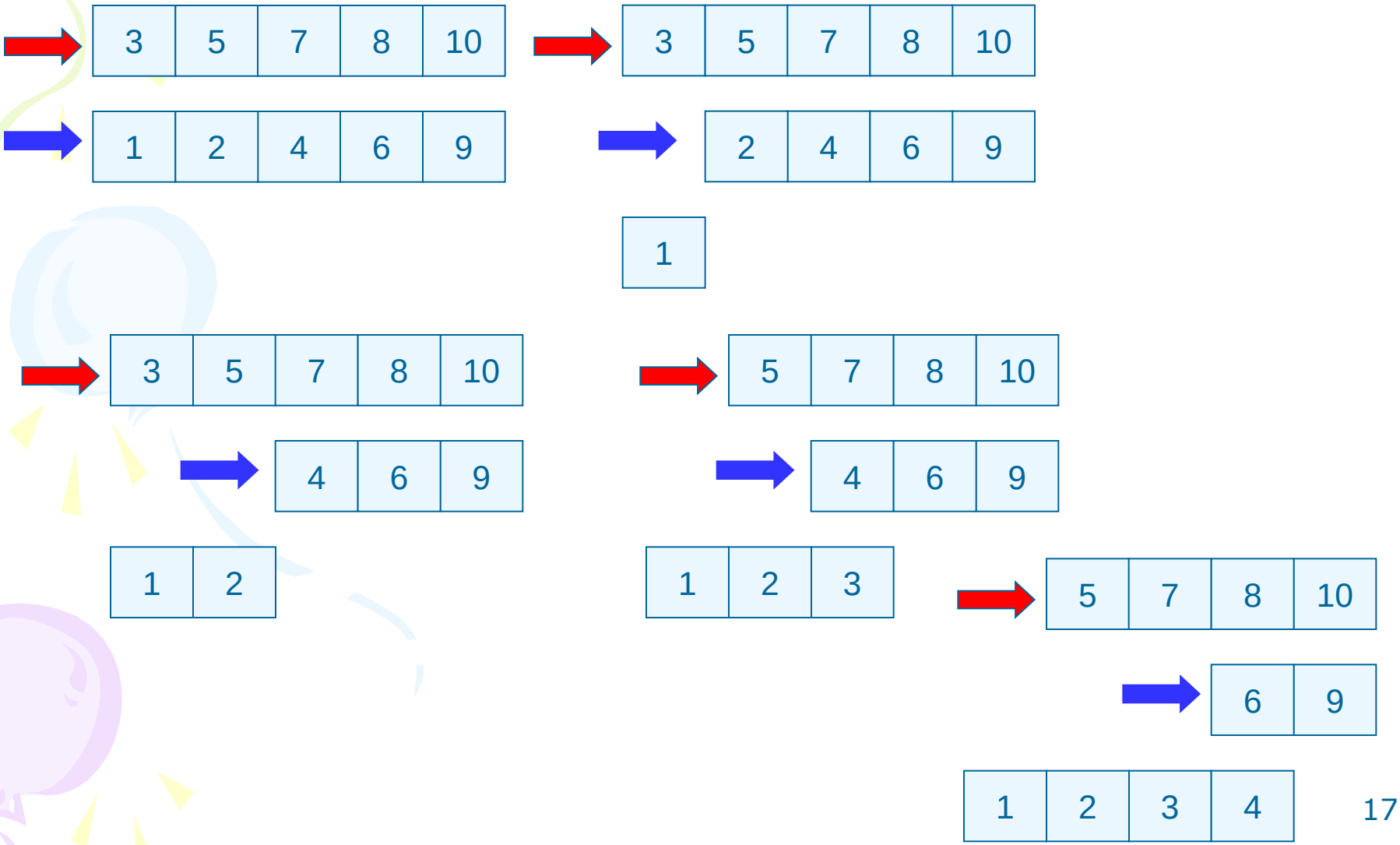
# Algorithm

```
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 k <  n+m
     if U[i] < V [j]
          E[k] = U[i] , i++
     else
          E[k] = V[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.
- You 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.

# Exercise: Recursive Processing

- Write a recursive algorithm for dealing a deck of cards. The parameters should be (i) the deck of undealt cards, and (ii) the person who is to receive the next card. Assume:
  - the players are seated around a table;
  - dealing begins with the player to the dealer's left;
  - each dealing step involves dealing one card to a player, then the dealer's attention moves to the next player to the left; and
  - dealing continues until no cards are left in the deck.

# Hint

```
function dealCards (deck, person)
{
    if (deck is empty)
        return;
    deal top card from deck to person;
    dealCards (rest of deck, personLeftOf(person));
}
```

# Exercise: Recursive Processing

- Write a recursive function **void recurTriangle ( int n, char ch )** which prints out an upside-down triangle. The parameter *ch* is the character to be used for drawing the triangle, and *n* is the number of characters on the first row. For example, if *n* is 7 and *ch* is **'+'**, then the output of the function should be:

```
+++++++
++++++
+++++
++++
+++
++
+
```

```
void recurTriangle(int n, char ch)
{
int i;

   if(n > 0)
        {
        for(i = 0; i < n; i++) printf("%c", ch);
        printf("\n");
        recurTriangle(n-1, ch);
        }
}
```

# 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.

# Homework

- Write a quicksort function to sort a singly linked list. Add this function to the linked list library.
- Hint: You should have a function
  - *for getting the Nth element in the linked list*
  - *Swapping two nodes in listed*

# Improve Quicksort

- Change the Pivot Selection strategy:
  - random element
  - median of three strategy
    - The median-of-three choice: take the first, the last and the middle element.
      Choose the median of these three elements.
      - **Example:**
      - 8, 3, 25, 6, 10, 17, 1, 2, 18, 5
      - The first element is 8, the middle - 10, the last - 5.
        The median of [8, 10, 5] is **8**

# Homework: Merge sort

- Return to the  file split – merge homework (with data in phone.dat)
- Read data from two splited files to arrays. Carry out mergesort and display the result on the screen.
- Write the sorted data to phone.dat.