# Lab 3: Sorting (Group Project)

This project will utilize the following sorting algorithms:

- Selection Sort, Insertion Sort, Shell Sort, Bubble Sort, Heap Sort, Merge Sort, Quick Sort, Radix Sort, and Counting Sort.
- Bonus exploration: Binary Insertion Sort, Shaker Sort, Flash Sort.

Details about the requirements can be found in the information below.

## 1 Programming

### 1.1 Algorithms

You are tasked with implementing all the above sorting algorithms in **C/C++** for **ascending order**. The implementation of bonus algorithms is encouraged for additional credit.

### 1.2 Experiments

For this project, the following scenario outlines the necessary steps for conducting the experiments:

```
for each Data Order S1
    for each Data Size S2
        - Create an original array A1 with Data Order S1 and Data Size S2
        for each Sorting Algorithm S3
            - Make a duplicate array A2 of the original array A1
            - Sort array A2 using the Sorting Algorithm S3, while:
                + Measuring the running time (in millisecs), and
                + Counting the number of comparisons in the algorithm
            - Take note of S1, S2, S3, running time and number of comparisons
        end for
    end for
end for
```

**1.2.1 Data Order** Evaluate the sorting algorithms on various data arrangements including **sorted** (in ascending order), **nearly sorted**, **reverse sorted**, and **randomized** data.
Refer to `DataGenerator.cpp` for more information.

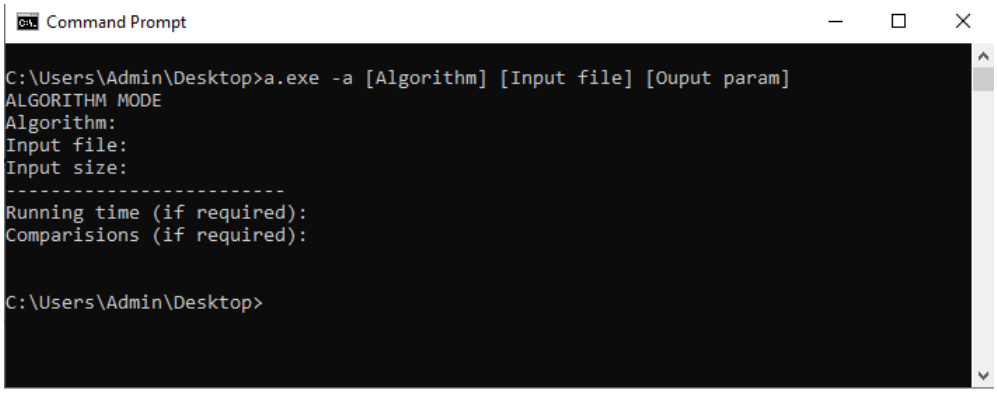
**1.2.2 Data Size** Evaluate the algorithms on datasets of varying sizes: `10,000`, `30,000`, `50,000`, `100,000`, `300,000`, and `500,000` elements.

### 1.3 Output specifications

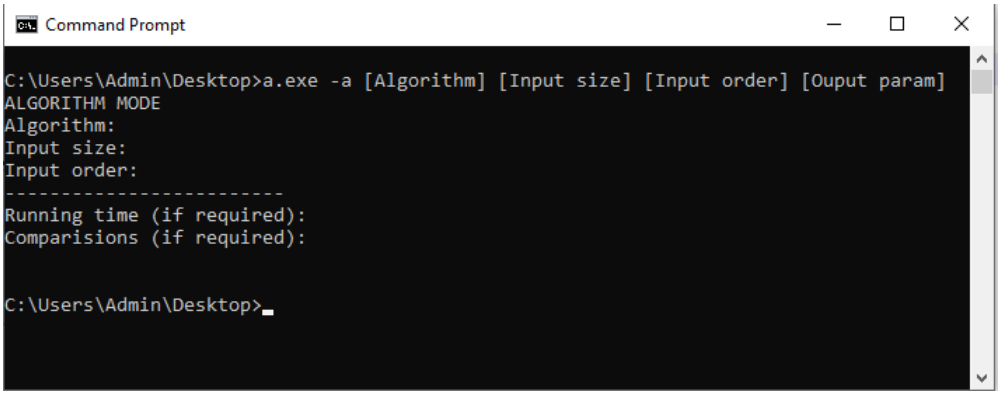
Your source code must be compiled into an executable file (.exe) that can be executed using commands in the command prompt.

1. **Algorithm mode**: This mode allows you to execute a specific sorting algorithm on input data. This data can be either user-provided or automatically generated. The mode then outputs the measured execution time and/or the number of comparisons performed by the algorithm.

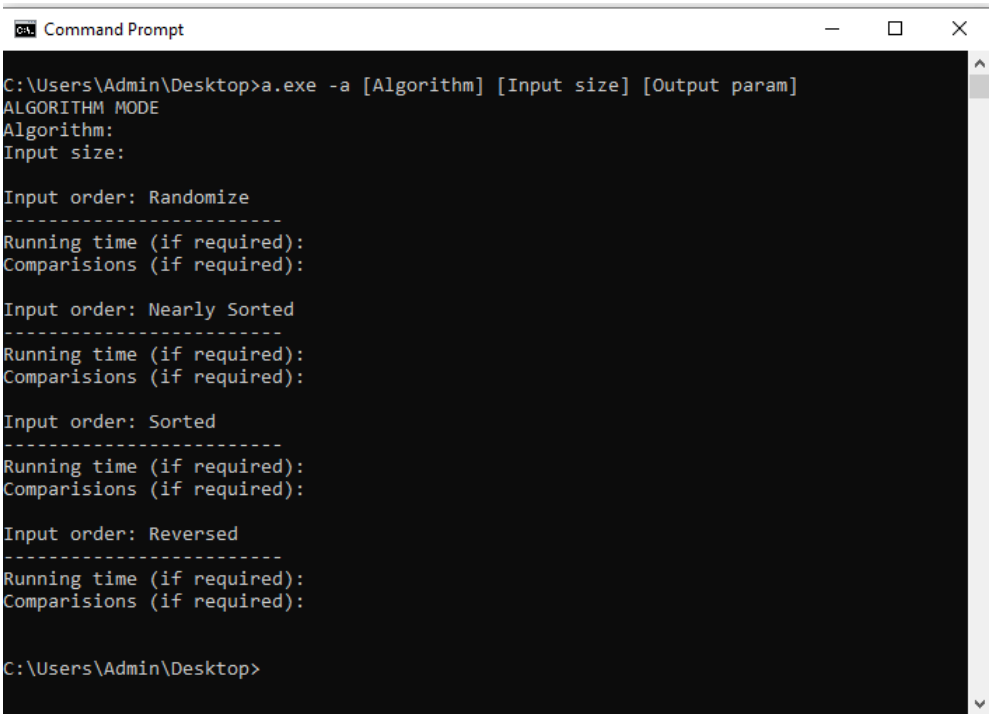
   - Command 1: Run a sorting algorithm on user-provided data.
     - **Prototype:** `[Execution file] -a [Algorithm] [Input filename]| [Output parameter(s)]`
     - **Example**: `a.exe -a radix-sort input.txt -both`
     - **Console output**:




   - Command 2: Run a sorting algorithm on the data generated automatically with specified size and order.
     - **Prototype**: `[Execution file] -a [Algorithm] [Input size] [Input order] [Output parameter(s)]`
     - **Example**: `a.exe -a selection-sort 50 -rand -time`
     - **Console output**:

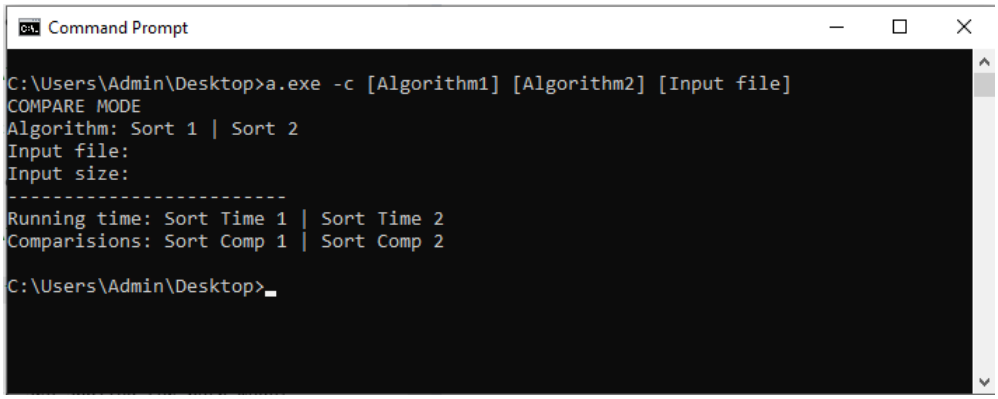


- Command 3: Run a sorting algorithm on ALL data arrangements of a specified size.
  - **Prototype**: `[Execution file] -a [Algorithm] [Input size] [Output parameter(s)]`
  - **Example**: `a.exe -a quick-sort 70000 -comp`
  - **Console output**:

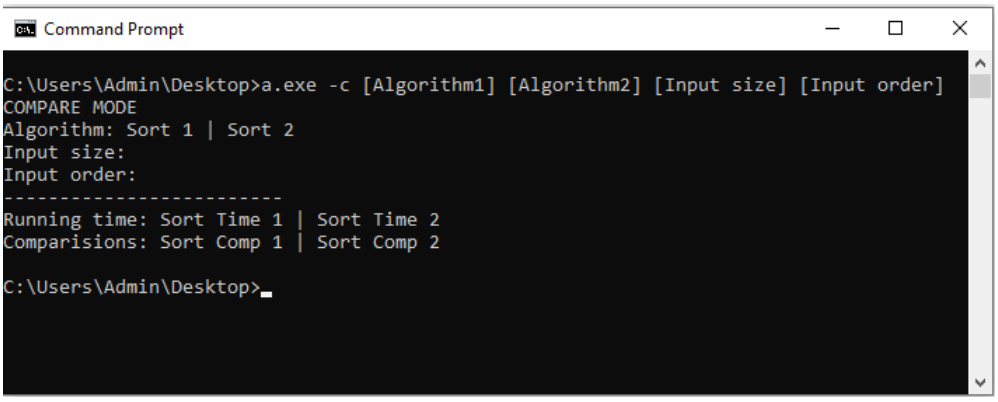



2. **Comparison mode:** This mode allows you to compare two sorting algorithms on input data. This data can be either user-provided or automatically generated. The mode then outputs the measured execution times and/or the number of comparisons performed by each algorithm.

- Command 4: Run two sorting algorithms on user-provided data.
  - **Prototype**: `[Execution file] -c [Algorithm 1] [Algorithm 2] [Input filename]`
  - **Example**: `a.exe -c heap-sort merge-sort input.txt`
  - **Console output**:



- Command 5: Run two sorting algorithms on the data generated automatically with specified size and order.
  - **Prototype**: `[Execution file] -c [Algorithm 1] [Algorithm 2] [Input size] [Input order]`
  - **Ex**: `a.exe -c quick-sort merge-sort 100000 -nsorted`
  - **Console output**:




3. **Input arguments:** *The following arguments are applied for both modes:*

   a. **Mode:**
   - **-a**: Algorithm mode
   - **-c**: Comparison mode

   b. **Algorithm name:** Lowercase, words are connected by "-" (Ex: selection-sort, binary-insertion-sort, ...)

   c. **Input size:** Integer ($\leq$ `1,000,000`)

   d. **Input order:**
   - **-rand**: randomized data
   - **-nsorted**: nearly sorted data
   - **-sorted**: sorted data
   - **-rev**: reverse sorted data

   e. **Given input (file):** Path to the input file. The file format is as follows:
   - $1^{st}$ line: an integer $n$, indicating the number of elements in the input data
   - $2^{nd}$ line: $n$ integers, separated by a single space

   f. **Output parameters**
   - **-time**: algorithms's running time
   - **-comp**: number of comparisions
   - **-both**: both above options

4. **Writing files:** In addition to the console output described above, you are required to write down the corresponding input(s) or output(s).

   - For Command 1 and Command 2: Write down the sorted array to the *"output.txt"* file.
   - For Command 2 and Command 5: Write down the generated input to the *"input.txt"* file.
   - For Command 3: Write down all four generated input:
     - *"input_1.txt"*: random order data
     - *"input_2.txt"*: nearly sorted data
     - *"input_3.txt"*: sorted data
     - *"input_4.txt"*: reversed data

   The file format (for both input and output files) is as follows:

   - $1^{st}$ line: an integer $n$, indicating the number of elements in the input data
   - $2^{nd}$ line: $n$ integers, separated by a single space

## 2 Report

Structure your report file with the following sections:

1. **Information page**
2. **Introduction page**
3. **Algorithm presentation**: This section delves into the implemented sorting algorithms. Here, you'll provide a comprehensive breakdown for each algorithm, including:
   - Core Concepts: Briefly discuss the core ideas behind each algorithm.
   - Step-by-step Explanations: Provide a clear and step-by-step explanation for each algorithm, including examples for more details.
   - Complexity Analysis: Analyze the time complexity of each algorithm. If applicable, also discuss the space complexity.
   - Variants and Optimizations: If any of the algorithms have known variants or optimizations, discuss them here.
4. **Experimental results and comments**:
   - You are required to organize the experimental results into FOUR tables, each representing one **Data order**. In each table, present the resulting statistics (i.e., running times or numbers of comparisons) of all sorting algorithms following a specific data arrangement. The table template is shown below:

| Data order: ... | | | | | | |
|---|---|---|---|---|---|---|
| **Data size** | 10,000 | | 50,000 | | ... | |
| **Resulting statics** | Running time | Comparision | Running time | Comparision | Running time | Comparision |
| Sorting algorithm 1 | | | | | | |
| Sorting algorithm 2 | | | | | | |
| ... | | | | | | |

- You are also required to make visualization by graphs.
  - There will be four LINE GRAPHs, each of which corresponds to a table of running times. In every graph, the horizontal axis is for `Data Size` and the vertical axis is for running time, as shown in Figure 1.

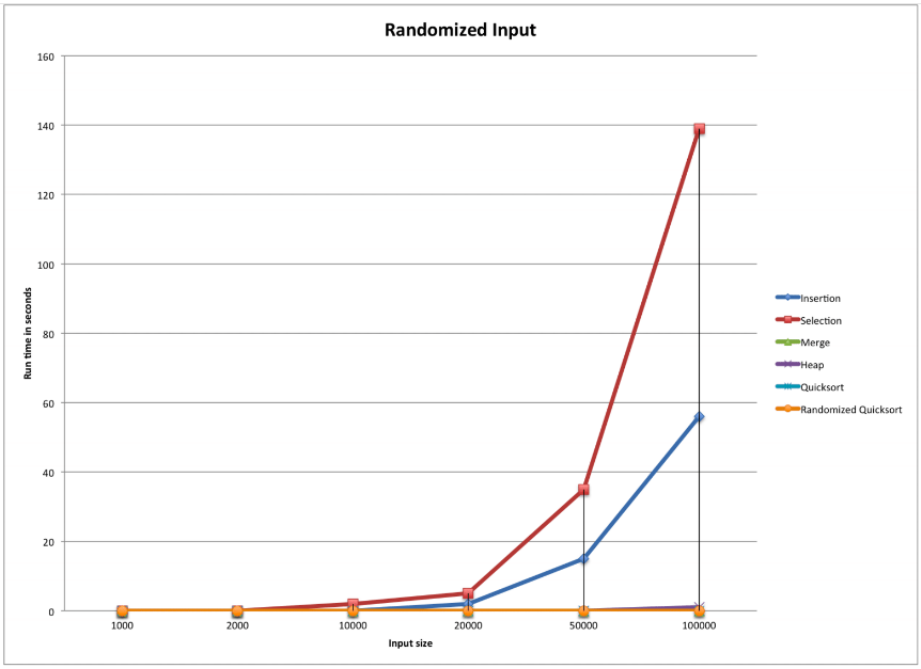



Figure 1: An example of a line graph for visualizing the algorithms' running times on randomized input data.

  - There will be four BAR CHARTs, each of which corresponds to a table of numbers of comparisons. In every graph, the horizontal axis is for `Data Size`, and the vertical axis is for the number of comparisons, as shown in Figure 2.
- Make comments based on your own observations on each graph (e.g., the fastest/slowest or the most/least comparisons algorithm(s) in each case, time or comparisons acceleration of algorithms, etc.). Explain your comments.
- Make an overall comment of algorithms on all `Data Order` and all `Data Size` (the fastest/slowest algorithms overall, grouping the stable/unstable algorithms, etc.)

5. **Project organization and Programming notes**: A brief explanation of how you organized your source codes, and notes of any special libraries/data structures used.

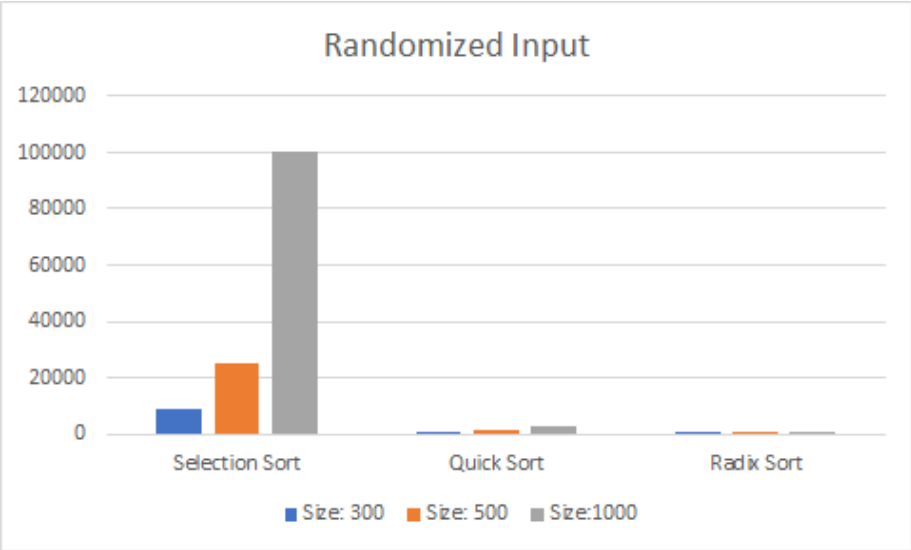



Figure 2: An example of a bar chart for visualizing the algorithms' numbers of comparisons on randomized input data.

6. **List of references**.

## 3 Submission

This is a 4-person group project. Formation of groups with fewer than 4 members requires permission from the instructors. Individual assignments will not be accepted.

- Create the folder <Group ID> to include the following materials:
  - SOURCE folder: the project's source codes, only files of extensions **.cpp** and **.h** are required.
  - Executable file: <Group ID>.exe (e.g. `01.exe`)
  - Report.pdf: the report file of extension **.pdf**.
  - Checklist.xlsx: the Excel template file filled with your information.
- Compress the above folder into a file of extension **zip** and name it following your Group ID (e.g. `01.zip`).
- Only one member representing the group submits the assignment.

Submission that violates any regulation will get a score of ZERO.

Plagiarism and Cheating will result in a score of ZERO for the entire course and will be subject to appropriate referral to the Management Board for further action.