Mini project

PM2.5 dust sensor simulation and data analysis

I. Description:

Students need to write a program in C or C++ with the appropriate functions and data structure to simulate PM2.5 dust sensor which measures the concenstration of dust particle with the size < 2.5 microns in ambient air. Main sensor specifications are:

- Measurement range: $0 \div 1000\ \mu g/m^3$
- Resolution: $0.1\ \mu g/m^3$

The tasks to do include:

1. Task 1:

Write a program which allow the user to provide the number of sensors, sampling time and measurement duration by using command-line statement to generate simulation data. The format of the command-line statement is as the folllowings:

```
C:\\dust_sim –n [num_sensors] –st [sampling] –si [interval]
```

Where:

- `dust_sim`: is the name of the compiled program file.
- `-n [num_sensors]` are a pair of input arguments to provide the number of sensors, `[num_sensors]` must be replaced by a specific positive integer value. If only one of these two appears in the command-line statement, error message must be delivered. If both of these two are not given in the statement, the default number of sensor is used and it is 1 (one).
- `-st [sampling]` are a pair of input arguments to provide the sampling time, `[sampling]` must be replaced by a specific positive integer value in second, the smallest sampling time allowed is 1 second. If only one of these two appears in the command-line statement, error message must be delivered. If both of these two are not given in the statement, the default sampling time is used and it is 30 seconds.
- `-si [interval]` are a pair of input arguments to provide the simulation/measurement duration, `[interval]` must be replaced by a specific positive integer value in hour, the smallest duration allowed is 1 hour. If only one of these two appears in the command-line statement, error message must be delivered. If both of these two are not given in the statement, the default duration is used and it is 24 hours.

The simulation data generated include the sensor identification number (sensor id), (simulated) measurement timestamp, and (simulated) sensor value. The starting time of the simulatiuon is identified by subtracting the current time in the system (computer time) with the simulation duration. The timezone should be default, it is usually the local time; student do not need to use any function or argument to change the timezone.

- The sensor id is generated in the range of 1 to `num_sensors`, where `num_sensors` is the number of sensor that the user provided in the command-line statement, e.g. if `num_sensors = 10` the program will create 10 sensors with the ids are 1, 2, 3,… , 10.
- The measurement timestamp (simulated) needs to be written in the format of YYYY:MM:DD hh:mm:ss, where:
  - YYYY – year, MM – month, DD – day.
  - hh – hour, mm – minute, ss – second.

  E.g: 2023:05:01 08:30:02

- The measurement value (simulated) is generated randomly with the precision of 1 digit after decimal point.

Notice: the simulation time (duration and timestamp) is not real-time, it is just computed in simulation, thus, the student do not use time delay functions such as sleep() or loop to create time delay.

The data generated needs to be stored in a file named "dust_sensor.csv"; if the file exists, the program can override the old file. This data file follows the CSV (comma-separated values) format, each field is separated by a comma. CSV file format can be referred in the url: https://www.ietf.org/rfc/rfc4180.txt. The data file needs to be in the same folder as the program file.

Example: Let an user write the command-line statement:

```
C:\\dust_sim -n 3 -st 60 -si 10
```

- Asumming that the user run the command line statement at 2023:05:08 10:00:00, the starting time of the simulation is at 2023:05:08 00:00:00. Both the starting time and the execution time are included.
- Data in the file "dust_sensor.csv" are as the following:

```
id,time,value
1,2023:05:08 00:00:00, 50.1
2,2022:05:08 00:00:00,24.2
3,2023:05:08 00:00:00, 200.5
1,2023:05:08 00:01:00,100.2
2,2023:05:08 00:01:00,55.4
3,2023:05:08 00:01:00,160.9
…
1,2023:05:08 10:00:00,120.2
2,2023:05:08 10:00:00,90.4
3,2023:05:08 10:00:00,351.0
```

The first line "id,time,value" is the header line.

2. Task 2:

Students need to write a program to process a csv with the same format as in task 1. The program must be executed with the following command-line statement:

`C:\\dust_process [data_filename.csv]`

Where:

- `dust_process`: is the compile program file
- `[data_filename.csv]` is the csv file consisting of the dust sensor data. In case the user does not provide the filename but type only `C:\\dust_process`, the program should use the default filename as "dust_sensor.csv".

For example: `C:\\dust_process dust_sensor_ee3490e.csv`

The program must be able to process at least 10000 data ponts which means that the input file `data_filename.csv` may consist of at least 10000 lines. The outcomes of data processing are as the following tasks. All tasks must be performed at once when the program is executed.

a. Task 2.1:

It is assumed that the dust concentration in the monitored environment can only be in the range of $5 \div 550.5\ \mu g/m^3$. Thus, the valid sensor values must be within this range, and any values which are not in this range are outliers. The program needs to check for the invalid sensor values, i.e. outliers

in the csv file and stored in a csv file named "dust_outlier.csv". An example of this file content is shown below

```
number of outliers: 3
id,time,value
1,2023:05:08 00:00:00,2.1
3,2023:05:08 19:03:00,-1
3,2023:05:08 21:06:00,560.2
```

In which, the first line is written as "number of outliers: X" with X is the number of outliers filtered out from the data file, in this example X = 3.

The valid sensor values are used to perform the rest of the tasks from task 2.2 onwards.

b. Tasks 2.2:

The dust concentration can be converted into Air Quality Index (AQI) as the followings:

Concentration c $[\mu g/m^3]$	$0 \leq c < 12$	$12 \leq c < 35.5$	$35.5 \leq c < 55.5$	$55.5 \leq c < 150.5$	$150.5 \leq c < 250.5$	$250.5 \leq c < 350.5$	$350.5 \leq c \leq 550.5$
AQI	0 ÷ < 50	50 ÷ <100	100 ÷ <150	150 ÷ <200	200 ÷ <300	300 ÷ <400	400 ÷ 500
Pollution level	Good	Moderate	Slightly unhealthy	Unhealthy	Very unhealthy	Hazardous	Extremely hazardous

The program needs to calculate the average dust concentration per hour, e.g. average dust concentration at 2023:05:08 02:00:00 is the average value of all the concentration values from 2023:05:08 01:00:00 to 2023:05:08 01:59:59. It also identify the AQI and pollution level with respect to that average value. The resusts should be store in a file named "dust_aqi.csv" with the same format as the below example:

```
id,time,value,aqi,pollution
1,2023:05:08 01:00:00, 50.1,137,Slightly unhealthy
2,2023:05:08 01:00:00,24.2,76,Moderate
3,2023:05:08 01:00:00, 200.5,250,Very unhealthy
1,2023:05:08 02:00:00,100.2,174,Unhealthy
2,2023:05:08 02:00:00,10.4,43,Good
3,2023:05:08 02:00:00,160.9,210,Very unhealthy
…
```

c. Tasks 2.3:

Identify the maximum (max), minimum (min) and the average concentration values over all the time (mean) measured by each sensor. The results must be stored in a file named "dust_summary.csv" with the same format as the below example:

```
id, parameter, time, value
1, max,2023:05:08 08:30:00,350.8
1, min,2023:05:08 09:31:03,5.6
1, mean,10:00:00 ,200.5
2, max,2023:05:08 08:35:00,300.8
2, min, 2023:05:08 09:32:03,15.6
2, mean,10:00:00, 110.5
3, max, 2023:05:08 09:05:02,120.6
3, min, 2023:05:08 09:21:03,20.8
3, mean,10:00:00,70.5
…
```

The time of the max and min values are the earliest timestamps these values appear in the input file. The time of the mean value is the simulation time interval.

d. Task 2.4:
Based on the outcomes of task 2.2, the program needs to calculate total number of hours for each pollution level at each sensor and stored the results in a file named "dust_statistics.csv" with the same format as the following example

```
id, pollution,duration
1,Good,2
1, Moderate,1
1, Slightly unhealthy,3
1,Unhealthy,0
1,Very unhealthy,2
1, Hazardous,2
1, Extremely hazardous,0
2,Good,1
2, Moderate,2
2, Slightly unhealthy,0
2,Unhealthy,4
2,Very unhealthy,1
2, Hazardous,0
2, Extremely hazardous,1
…
```

3. Task 3:

It is assumed that the users need to send the output data of task 2.2 over a communication protocol. The data packet is a byte array which must be created and follow the below structure

Start byte	Packet Length	ID	Time	PM2.5 concentration	AQI	Checksum	Stop byte
0x7A (1 byte)	1 byte	1 byte	4 bytes	4 bytes	2 byte	1 byte	0x7F (1 byte)

Where:

- Start byte (1 byte) is the first byte in the packet and always has the value of 0x7A.
- Stop byte (1 byte) is the last byte in the packet and always has the value of 0x7F.
- Packet length is the size of the packet including the start byte and stop byte.
- Id is the identification number of the sensor (sensor ID) and must be a positive value (>0)
- Time is the measurement timestamp in **second** which follow Unix timestamp format.
- PM2.5 concentration is the PM2.5 dust concentration value which is a 4-byte real number represented with IEEE 754 single precision floating-point standard.
- AQI is the air quality index and is a 2-byte integer.
- Checksum is the byte to verify the data packet and is calculated by using two complement algorithm of the byte group including [packet length, id, time, PM2.5 concentration, AQI]

All the numbers (integer and real ones) are represented as big-endian.

If the user executes the following command-line statement:

```
C:\\ dust_convert [data_filename.csv] [hex_filename.dat]
```

Where

- `[data_filename.csv]` is an input file which has the same format described in task 2.2.
- `[hex_filename.dat]` is the output file in text format with the extension of ".dat".

The users must provide both the two filenames, otherwise it is an invalid statement.

The programm should:
- Read each line of the input file, i.e.: `[data_filename.csv]`
- Convert each data line into the data packet as described above, each byte is separated by a space character and represented as hex number
- Write each packet in one line in the output file, i.e. `[hex_filename.dat]`
- Overide the output file `[hex_filename.dat]` if it has been existed.
- Be able to process at least 10000 data ponts which means that the input file `data_filename.csv` may consist of at least 10000 lines.

For example:

`C:\\dust_convert dust_aqi.csv hex_packet_ee3491.dat`

A line of "2,2023:06:07 11:00:00,99.8,173,Unhealthy" exited in the file named "dust_aqi.csv" is converted into

7A 0F 02 64 80 00 C0 42 C7 99 9A 00 AD 62 7F

II. Other technical requirements:

The program needs to store any run-time errors occurring in log files, there must be 3 different log files for 3 tasks in section I. They are named as task1.log, task2.log and task3.log for task 1, task 2 and task 3 respectively. Each error must be written in a line in the corresponding log file with the format below:

Error AB: DESCRIPTION

Where:
- AB is the error code which is a 2-digit number (if the number is smaller than 10, there must be a leading zero digit, i.e.: 01, 02, …)
- DESCRIPTION is the detail of the error.

1. Errors may happen when executing task 1:
- Wrong command-line statement, e.g.: lack of the 1 or a few required command-line argument. The error message can be "Error 01: invalid command".
- Invalid value of the command-line argument, e.g. negative number of sensors. The error message can be "Error 02: invalid argument".
- "dust_sensor.csv" file is existing and is a read-only file. The error message can be "Error 03: dust_sensor.csv access denied"

2. Errors may happen in task 2:
- The input file `data_filename.csv` does not exist or is not allowed to access. The error message can be "Error 01: input file not found or not accessible"
- The input file `data_filename.csv` does not have proper format as required, e.g. it has no header file, wrong number of comma, or even consists of completely different data format. The error message can be "Error 02: invalid csv file format"
- The user types the wrong command-line format, e.g.: one or both the two filenames are missing. "Error 03: invalid command"
- The input file contains wrong data:
  - All the data fields in one line are blank, e.g.: ", , "
  - Id is blank or invalid, e.g.: "-1, 2023:05:08 00:00:00, 50.1"
  - Time is blank or invalid, e.g.: "1,2023:05:08 00:00:, 50.1"
  - Concentration value is blank, e.g.: "1,2023:05:08 00:00:00, "

  The error message must include the line number in the input file in which the error happens, i.e.: "Error 04: data is missing at line X" where X is the line number. The first line in the input file

which is the header line "id,time,value" is line 0 (zero), the next lines onwards are data line and are numbered from 1 (one).

3. Errors may happen in task 3:

- The input file `data_filename.csv` does not exist or is not allowed to access. The error message can be "Error 01: input file not found or not accessible"
- The input file `data_filename.csv` does not have proper format as required, e.g. it has no header file, wrong number of comma, or even consists of completely different data format. The error message can be "Error 02: invalid csv file format"
- The user types the wrong command-line format, e.g.: one or both the two filenames are missing. "Error 03: invalid command"
- The output file `hex_filename.dat` is existing and cannot be overriden. Thông báo lỗi "Error 05: cannot override hex_filename.dat"
- The input file contains wrong data:
    - All the data fields in one line are blank, e.g.: ", , "
    - Id is blank or invalid, e.g. "-1, 2023:05:08 00:00:00, 50.1"
    - Time is blank or invalid, e.g. "1,2023:05:08 00:00:, 50.1"
    - Concentration value is blank, e.g. "1,2023:05:08 00:00:00, "

  The error message must include the line number in the input file in which the error happens, i.e.: "Error 04: data is missing at line X" where X is the line number. The first line in the input file which is the header line "id,time,value" is line 0 (zero), the next lines onwards are data line and are numbered from 1 (one).

4. The students can suggest more errors which may happen but not be listed above. Those errors should be stored in the respective log file and described in the report.

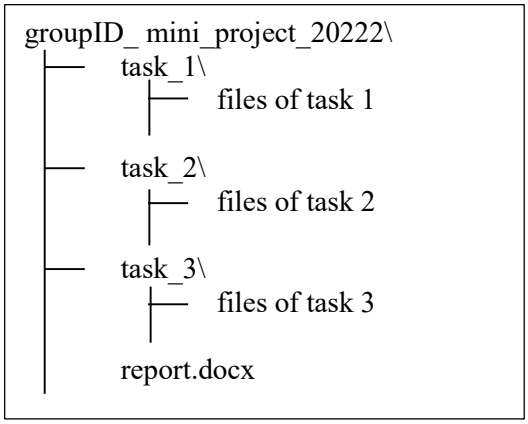
III. **Program design:**

The students must use top-down approach to design the program. It is required to draw the top-down approach diagram to illustrate the relationship between the functions in the program together with brief description in the report.

The students need to draw at least two flowcharts:

- One flowchart of the overall program
- And at least one flowchart for one important function in the program. The student can draw more than one flowchart for different functions.

The students must provide the folder structure and file structures with brief description as the followings:



Where the project root folder is named as "groupID _ mini_project_20222" and three subfolders "task_1", "task_2" and "task_3" which contain the related file. "report.docx" is the report file and should be placed in the project root folder. The *groupID* in the filename should be replaced by the group ID.

IV. Coding styles:

Coding style needs to be consistent throughout the program and follows the GNU style described in the following link: https://www.gnu.org/prep/standards/html_node/Writing-C.html
Shortly, it should be as the followings:

- The structure of the code should be clean and easy to read by using proper indentation, parenthesis, code block, line break and spacing.
- Comments are provided to explain the program more clearly but not to paraphrase the code statement.
- The names of functions and variables must be in English, compact and self-described.
- Hard-coding should be avoided.

Notice: The students cannot use any third-party libraries rather than the C/C++ standard library.

V. The tools:

Editor: Visual studio code (https://code.visualstudio.com/download)
Compiler: gcc or g++ in MinGW-w64 (https://sourceforge.net/projects/mingw-w64/)
The students should also mention in the report that the program is written in which Operating System (Windows, Linux, MacOS).

VI. Report and submission guidlines:

- The students do the mini project in a group.
- The whole project needs to be organized in a folder as describe in section III.
- The studens must write an English report in a **Word** file named as "report.docx" which should not exceed 4 A4 pages and should not include the source code. The report must follow IEEE template which is attached in the Team Assignment.
- The content of the report must be:
    - Introduction of main idea: Brief description of the program design, the top-down approach diagram, main data structures, the folder structure, the source code files (if there are multiple source code files) and the standard libraries used.
    - Detailed design: introduction of the new data structures defined by students to handle the data (if any), description of the function designs including the function call syntax (function name, argument list and returning value) and inputs/outputs, pre-conditions, post-conditions; at least two flowcharts as mentioned in section III.
    - Results and evaluations: present the results of the program execution and its performance.
    - Conclusions: briefly conclude what have been done and what have NOT been done; provide a table of group member contribution as the below example:

Student names	Tasks	Percentage of contribution
Nguyen Van A	1, 2.1, 2.2	50%
Nguyen Van B	2.3, 2.4, 3	50%

      If only one student completes all the work and the other do nothing, one can write the percentage of contribution as 100% and 0% respectively.
    - References (If any).
- The students must compress the whole project folder in a zip file and name it as "groupId_mini_project_20222.zip" for submission. Please take note that it must be a ZIP file but NOT any other compression files like .rar.
    - Keep only the source codes, execution files and the Word report file.
    - Unrelated files should be removed before submitting.
    - The "groupID" in the file name must be replace by the group ID, e.g.: "20221234_20222345_mini_project_20222.zip"
- Students must submit the zip file above in Team Assignment by the deadline specified there. Do NOT submit via email, Teams chat or any other channels. Only ONE submission per group is required.

- If there are concerns on anything else which is NOT mentioned in this project instruction, the students can contact the lecturer for clarification. **It is highly recommended to ask the questions in class Teams rather than private discussion with the lecturer so that every student in the class is informed unless the question is too personal.**

VII. Evaluations:

- The mini project is evaluated as below:
  - All the tasks are completed, no run-time error, proper error handling and creative implementation (4 marks)
  - Clean and reusable design (2 marks)
  - Good coding style (2 marks)
  - Clear and well-structure report properly following template and highly consistent with the source code (2 marks)
- The students must do the project themselves. Do NOT copy others' works. The group should keep their work confidential. If any two or more groups have the similar source codes and/or reports, all the works of those groups are unacceptable and are considered as they have not submitted yet.
- No late submission is allowed.
- Good performance in the mini project can be awarded bonus points in course progress evaluation.
- **The group who does not submit the mini project will lose 3 point (over 10) in the course progress evaluation.**

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