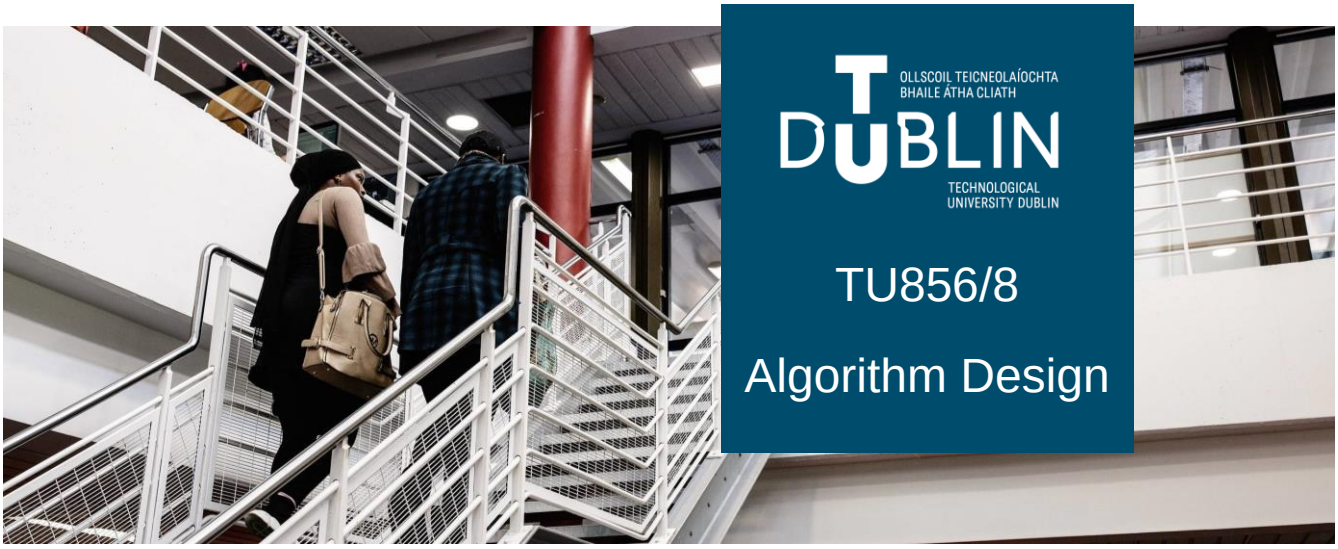

OLLSCOIL TEICNEOLAÍOCHTA BHAILE ÁTHA CLIATH
DUBLIN
TECHNOLOGICAL UNIVERSITY DUBLIN

TU856/8

Algorithm Design

TU856/8 ASSIGNMENT 2023/24

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INTRODUCTION

An engineering company manufactures aeronautical equipment on 4 different production lines at its factory in Dublin. The production line is sophisticated and audited to the highest quality standards. Each production line is used for the manufacture of multiple products in a multi-stage production process which ends when the product is packed for dispatch.
Quality Assurance (QA) is important to the company. Each product is manufactured in a single identified batch (group) and faults or issues identified at every stage are logged and tracked by a QA engineer.

Working in the company's IT department, you have been given access to the QA logs of each production line. You have been asked to assist the management team in analysing the QA data from the manufacturing process. The QA logs contain the following data and are newly created for each month:

a. Line Code – Numeric
b. Batch code - Numeric
c. Batch date & time – numbered for day of month, hour of day, minute of hour.
d. Product Id - numeric
e. Issue Code & description - numeric + text
f. Resolution code & description – numeric + text
g. Reporting employee id – numeric

DESIGN REQUIREMENTS

TASK 1

- The production line logs are either ordered by date & time or may be in a random order for each day. Prepare a report for each line in Product id, Issue code, date & time order.
- There are huge amounts of data stored, the running time of this algorithm should be O(NLog(N)) or better.

TASK 2

- Due to changes in the manufacturing process, the same product can be manufactured on different lines.

- Prepare a report which uses a *single list* to report (order) issue codes by product Id and line Id for all production lines.
- There are huge amounts of data stored, the running time of this algorithm should be O(N) or better.

TASK 3

- Provide a facility to search for the earliest occurrence of an issue code for a given product id across all production lines.
- There are huge amounts of data stored, the running time of this algorithm should be O(Log(N)) or better.

TASK 4

- Provide a report which summarises the number of issues reported for a product across all production lines.
- There are huge amounts of data stored, the running time of this algorithm should be O(N) or better.

Your documentation should show how each algorithm meets the running time requirement.

DELIVERABLES

1. Design a data structure for the project.
2. Create test data for each line. e.g. >10 issues/products per line.
3. Test your project – outline how you will ensure that your implementation meets the design requirement.
4. Produce a flowchart for Task 2.
5. Produce pseudocode for Tasks 1-4.
6. Produce working C code for tasks 1-4.
7. Create a project report outlining the brief, your design for each task, your test plan for each task and the pseudocode + code.
    a. The report should be submitted in MS Word .docx format OR Adobe PDF format .pdf. Reports not meeting these requirements will not be marked.
    b. Code should be readable.
    c. Submit by 5pm 7th April 2024. Late submission -10% per day.

Projects will be demoed in the lab. The sequence of the demo should be:

1. Display data from each production line
2. Display data from each production line meeting requirements of Task1
3. Display data from all production lines meeting requirements of Task2
4. Prompt for search and display result meeting requirements of Task3
5. Display summary data meeting requirements of Task4

Unanswered or incorrect responses to questions on the design or implementation will result in an NG. Marks are allocated equally to all sections, including the demo.

DATA STRUCTURE

To tackle the following tasks effectively, a structured approach has been adopted to enclose the essential attributes for each log, which are Line Code, Batch Code, Batch Date & Time, Product Id, Issue Code & Description, Resolution Code & Description, and Reporting Employee Id. In addition, the “DateTime” structure has been created specifically to articulate the Batch Date & Time attributes within the “ProductionLine_Log” structure. The “DateTime” structure consists of three integer fields: “dayofmonth”, “hourofday”, and “minuteofhour”.

```
#include <stdio.h>
#include <stdlib.h>


// Define DateTime structure
struct DateTime
{
    int dayofmonth;
    int hourofday;
    int minuteofhour;
};

// Define ProductionLine_Log structure
struct ProductionLine_Log
{
    int LineCode;
    int BatchCode;
    struct DateTime BatchDateTime;
    int ProductId;
    int IssueCode;
    char IssueDescription[100];
    int ResolutionCode;
    char ResolutionDescription[100];
    int ReportingEmployeeId;
};
```

TEST DATA

In the main function, a set of test data representative of ProductionLine_Logs has been generated to illustrate the information in each of these logs.

```
// Example ProductionLine_Log array
    struct ProductionLine_Log logs_data[] =
    {
        {1, 101, {1, 20, 45}, 1001, 10, "Defect in wing", 10, "Resolved by replacing
        faulty component", 100},
        {2, 102, {1, 5, 45}, 1003, 12, "Fire detection system malfunction", 12,
        "Resolved by conducting system testing", 105},
        {5, 105, {1, 11, 45}, 1002, 15, "Engine malfunction", 15, "Resolved by
        replacing affected parts", 102},
```

```
        {1, 107, {1, 7, 45}, 1001, 1, "Product damage", 1, "Resolved by adding final
        quality checks", 100},
        {9, 102, {1, 16, 45}, 1003, 3, "Shipping delay", 3, "Resolved by increasing
        number of couriers", 105},
        {6, 103, {1, 23, 45}, 1005, 15, "Engine malfunction", 15, "Resolved by
        replacing affected parts", 102},
        {1, 111, {1, 10, 45}, 1001, 17, "Transportation issue", 17, "Resolved by
        improving transportation methods", 100},
        {3, 116, {1, 6, 45}, 1006, 20, "Customer complaint", 20, "Resolved with
        personalised solutions", 105},
        {1, 109, {1, 22, 45}, 1002, 15, "Engine malfunction", 15, "Resolved by
        replacing affected parts", 102},
        {8, 107, {1, 21, 45}, 1005, 6, "Labelling issue", 6, "Resolved by
        implementing revised labelling procedures", 100},
        {7, 112, {1, 18, 45}, 1001, 12, "Fire detection system malfunction", 12,
        "Resolved by conducting system testing", 105},
        {1, 108, {1, 4, 45}, 1007, 30, "Staff shortage", 30, "Resolved by hiring
        temporary staff", 102},
    };
```

TASK 1

The primary objective of this task revolves around the creation of a report for each production line, sorted based on Product Id, Issue Code, and Date & Time attributes. To effectively tackle this task, the Merge Sort algorithm emerges as the most suitable choice due to its efficiency in managing large datasets. In fact, Merge Sort demonstrates admirable performance with a worst-case time complexity of O(NLog(N)).

To address the task, a total of 3 functions have been implemented.

The initial function, named "merge", plays an important role in merging two subarrays within the logs_data array. Using temporary arrays, this function copies data from the original array into these temporary arrays, and then merges them back into the original array based on specific criteria such as Product ID, Issue Code, and Batch Date & Time. During this process, the merge function operates with a time complexity of O(N), moving across each element precisely once.

Subsequently, the "MergeSort" function is employed to divide the array into smaller subarrays before merging them in a sorted order using the merge function. This divide-and-conquer strategy contributes to MergeSort's time complexity of O(NLog(N)), ensuring efficient sorting even with substantial amount of data.

In conclusion, the "PrintReport" function is created to meet the specific requirements of printing the sorted Production Line Report.

Pseudocode

```
#Merge two subarrays of logs_data[]
#First subarray goes from left to mid
#Second subarray goes from mid+1 to right
Function merge(logs_data[], left, mid, right)
    left_size := mid - left + 1
    right_size := right - mid
```

```
#Create temporary arrays
temp_left := left_size
temp_right := right_size

#Copy data to temporary arrays temp_left[] and temp_right[]
for i := 0 to left_size-1 do
    temp_left[i] := logs_data[left + i]
end for

for j := 0 to right_size-1 do
    temp_right[j] := logs_data[mid + 1 + j]
end for

#Merge the temporary arrays back into logs_data[]
i := 0 #initial index of first subarray
j := 0 #initial index of second subarray
k := left #initial index of merged subarray
while i < left_size and j < right_size do
    #Compare based on Product ID, Issue Code and Batch Date & Time
    if temp_left[i].ProductId < temp_right[j].ProductId or
       (temp_left[i].ProductId = temp_right[j].ProductId and
       temp_left[i].IssueCode < temp_right[j].IssueCode) or
       (temp_left[i].ProductId = temp_right[j].ProductId and
       temp_left[i].IssueCode = temp_right[j].IssueCode and
       (temp_left[i].BatchDateTime.dayofmonth <
       temp_right[j].BatchDateTime.dayofmonth or
       (temp_left[i].BatchDateTime.dayofmonth =
       temp_right[j].BatchDateTime.dayofmonth and
       (temp_left[i].BatchDateTime.hourofday <
       temp_right[j].BatchDateTime.hourofday or
       (temp_left[i].BatchDateTime.hourofday =
       temp_right[j].BatchDateTime.hourofday and
       temp_left[i].BatchDateTime.minuteofhour <
       temp_right[j].BatchDateTime.minuteofhour))))) then
          logs_data[k] := temp_left[i]
          i := i + 1
    else
          logs_data[k] := temp_right[j]
          j := j + 1
    end if
    k := k + 1
end while

#Copy the remaining elements of temp_left[], if there are any
while i < left_size do
    logs_data[k] := temp_left[i]
    i := i + 1
    k := k + 1
end while

#Copy the remaining elements of temp_right[], if there are any
while j < right_size do
    logs_data[k] := temp_right[j]
    j := j + 1
    k := k + 1
end while
```

```
end function


#Merge Sort function to sort logs_data[] based on Product ID, Issue Code
and Batch Date & Time
Function mergeSort(logs_data[], left, right)
    if left < right then
        mid := left + (right - left) / 2

        #Sort left and right halves
        mergeSort(logs_data, left, mid)
        mergeSort(logs_data, mid + 1, right)

        #Merge sorted halves
        merge(logs_data, left, mid, right)
    end if
end function


Function printReport(logs_data[], size)
    print("Sorted Production Line Report:")

    for i := 0 to size-1 do
        print("Product ID: ", logs_data[i].ProductId)
        print("Issue Code: ", logs_data[i].IssueCode)
        print("Date & Time: ", logs_data[i].BatchDateTime.dayofmonth, "
        (day of the month) ", logs_data[i].BatchDateTime.hourofday, ":",
        logs_data[i].BatchDateTime.minuteofhour, " (time)")
        print()
    end for
end function
```

C code

```c
#include <stdio.h>
#include <stdlib.h>


// Define DateTime structure
struct DateTime
{
    int dayofmonth;
    int hourofday;
    int minuteofhour;
};

// Define ProductionLine_Log structure
struct ProductionLine_Log
{
    int LineCode;
    int BatchCode;
    struct DateTime BatchDateTime;
```

```
    int ProductId;
    int IssueCode;
    char IssueDescription[100];
    int ResolutionCode;
    char ResolutionDescription[100];
    int ReportingEmployeeId;
};


// Merge two subarrays of logs_data[]
// First subarray goes from left to mid
// Second subarray goes from mid+1 to right
void merge(struct ProductionLine_Log logs_data[], int left, int mid, int right)
{
    int i, j, k;
    int left_size = mid - left + 1;
    int right_size = right - mid;

    // Create temporary arrays
    struct ProductionLine_Log temp_left[left_size], temp_right[right_size];

    // Copy data to temporary arrays temp_left[] and temp_right[]
    for (i = 0; i < left_size; i++)
    {
        temp_left[i] = logs_data[left + i];
    }
    for (j = 0; j < right_size; j++)
    {
        temp_right[j] = logs_data[mid + 1 + j];
    }

    // Merge the temporary arrays back into logs_data[]
    i = 0; //initial index of first subarray
    j = 0; //initial index of second subarray
    k = left; //initial index of merged subarray
    while (i < left_size && j < right_size)
    {
        // Compare based on Product ID, Issue Code and Batch Date & Time
        if (temp_left[i].ProductId < temp_right[j].ProductId ||
            (temp_left[i].ProductId == temp_right[j].ProductId && temp_left[i].IssueCode
            < temp_right[j].IssueCode) ||(temp_left[i].ProductId ==
            temp_right[j].ProductId && temp_left[i].IssueCode == temp_right[j].IssueCode
            && (temp_left[i].BatchDateTime.dayofmonth <
            temp_right[j].BatchDateTime.dayofmonth ||
           (temp_left[i].BatchDateTime.dayofmonth ==
           temp_right[j].BatchDateTime.dayofmonth &&
          (temp_left[i].BatchDateTime.hourofday < temp_right[j].BatchDateTime.hourofday
           ||(temp_left[i].BatchDateTime.hourofday ==
```

```
            temp_right[j].BatchDateTime.hourofday &&
            temp_left[i].BatchDateTime.minuteofhour <
            temp_right[j].BatchDateTime.minuteofhour))))))
        {
            logs_data[k] = temp_left[i];
            i++;
        }
        else
        {
            logs_data[k] = temp_right[j];
            j++;
        }
        k++;
    }


    // Copy the remaining elements of temp_left[], if there are any
    while (i < left_size)
    {
        logs_data[k] = temp_left[i];
        i++;
        k++;
    }

    // Copy the remaining elements of temp_right[], if there are any
    while (j < right_size)
    {
        logs_data[k] = temp_right[j];
        j++;
        k++;
    }
}


/* Merge Sort function to sort logs_data[] based on Product ID, Issue Code and Batch
Date & Time */
void mergeSort(struct ProductionLine_Log logs_data[], int left, int right)
{
    if (left < right)
    {
        int mid = left + (right - left) / 2;

        // Sort left and right halves
        mergeSort(logs_data, left, mid);
        mergeSort(logs_data, mid + 1, right);

        // Merge sorted halves
        merge(logs_data, left, mid, right);
    }
```

```c
}


// Function to print the sorted report
void printReport(struct ProductionLine_Log logs_data[], int size)
{
    printf("Sorted Production Line Report:\n");

    for (int i = 0; i < size; i++)
    {
        printf("Product ID: %d\n", logs_data[i].ProductId);
        printf("Issue Code: %d\n", logs_data[i].IssueCode);
        printf("Date & Time: %d (day of the month) %d:%d (time)\n",
        logs_data[i].BatchDateTime.dayofmonth, logs_data[i].BatchDateTime.hourofday,
        logs_data[i].BatchDateTime.minuteofhour);
        printf("\n");
    }
}


int main()
{
    // Example ProductionLine_Log array
    struct ProductionLine_Log logs_data[] =
    {
        {1, 101, {1, 20, 45}, 1001, 10, "Defect in wing", 10, "Resolved by replacing
         faulty component", 100},
        {2, 102, {1, 5, 45}, 1003, 12, "Fire detection system malfunction", 12,
         "Resolved by conducting system testing", 105},
        {5, 105, {1, 11, 45}, 1002, 15, "Engine malfunction", 15, "Resolved by
         replacing affected parts", 102},
        {1, 107, {1, 7, 45}, 1001, 1, "Product damage", 1, "Resolved by adding final
         quality checks", 100},
        {9, 102, {1, 16, 45}, 1003, 3, "Shipping delay", 3, "Resolved by increasing
         number of couriers", 105},
        {6, 103, {1, 23, 45}, 1005, 15, "Engine malfunction", 15, "Resolved by
         replacing affected parts", 102},
        {1, 111, {1, 10, 45}, 1001, 17, "Transportation issue", 17, "Resolved by
         improving transportation methods", 100},
        {3, 116, {1, 6, 45}, 1006, 20, "Customer complaint", 20, "Resolved with
         personalised solutions", 105},
        {1, 109, {1, 22, 45}, 1002, 15, "Engine malfunction", 15, "Resolved by
         replacing affected parts", 102},
        {8, 107, {1, 21, 45}, 1005, 6, "Labelling issue", 6, "Resolved by
         implementing revised labelling procedures", 100},
        {7, 112, {1, 18, 45}, 1001, 12, "Fire detection system malfunction", 12,
         "Resolved by conducting system testing", 105},
        {1, 108, {1, 4, 45}, 1007, 30, "Staff shortage", 30, "Resolved by hiring
         temporary staff", 102},
```

```
    };

    /* Determine the number of logs in the array to ensure that the logs_number
    variable holds the correct number of logs, even if the size of the array
    changes in the future. */
    int logs_number = sizeof(logs_data) / sizeof(logs_data[0]);

    // Display logs_data
    printf("Unsorted Production Line Report:\n");

    for (int i = 0; i < logs_number; i++)
    {
        printf("Production Line: %d\n", logs_data[i].LineCode);
        printf("Batch Code: %d\n", logs_data[i].BatchCode);

        printf("Batch Date & Time: %d (day of the month) %d:%d (time)\n",
        logs_data[i].BatchDateTime.dayofmonth, logs_data[i].BatchDateTime.hourofday,
        logs_data[i].BatchDateTime.minuteofhour);
        printf("Product ID: %d\n", logs_data[i].ProductId);
        printf("Issue Code: %d\n", logs_data[i].IssueCode);
        printf("Issue Description: %s\n", logs_data[i].IssueDescription);
        printf("Resolution Code: %d\n", logs_data[i].ResolutionCode);
        printf("Resolution Description: %s\n", logs_data[i].ResolutionDescription);
        printf("Reporting Employee ID: %d\n", logs_data[i].ReportingEmployeeId);
        printf("\n");
    }

    // Perform merge sort on logs_data based on Product ID
    mergeSort(logs_data, 0, logs_number - 1);

    // Print the sorted report
    printReport(logs_data, logs_number);

    return 0;
}
```

TASK 2

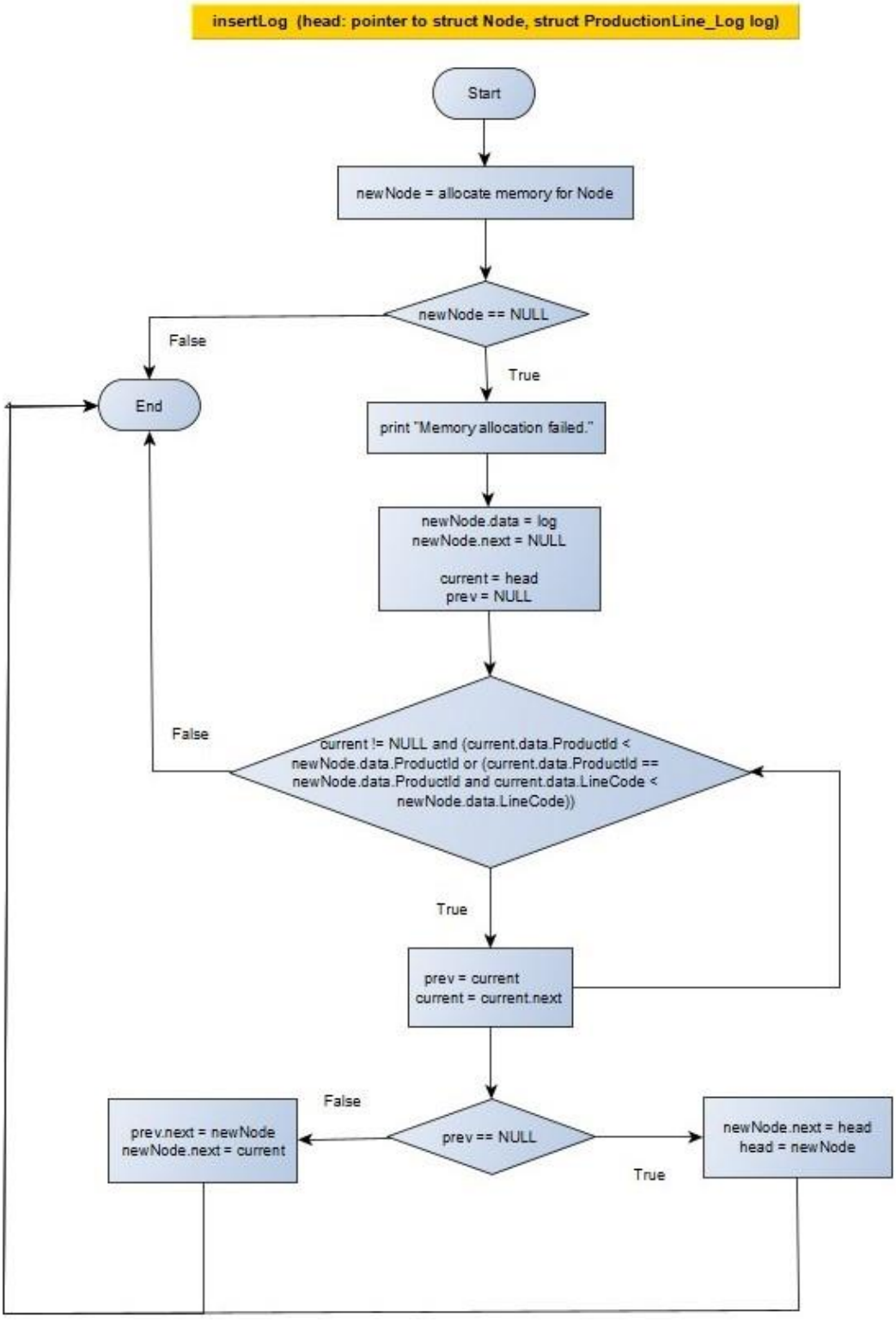
The primary aim of this task is to create a report that groups together issues related to the same product and production line. In order to meet the requirements of this task, a linked list data structure is used to organize and manage the logs from the production lines. This choice of design is driven by the necessity to preserve the order of logs based on their Product ID and Line Code attributes, which in turn facilitates the efficient sorting of data.

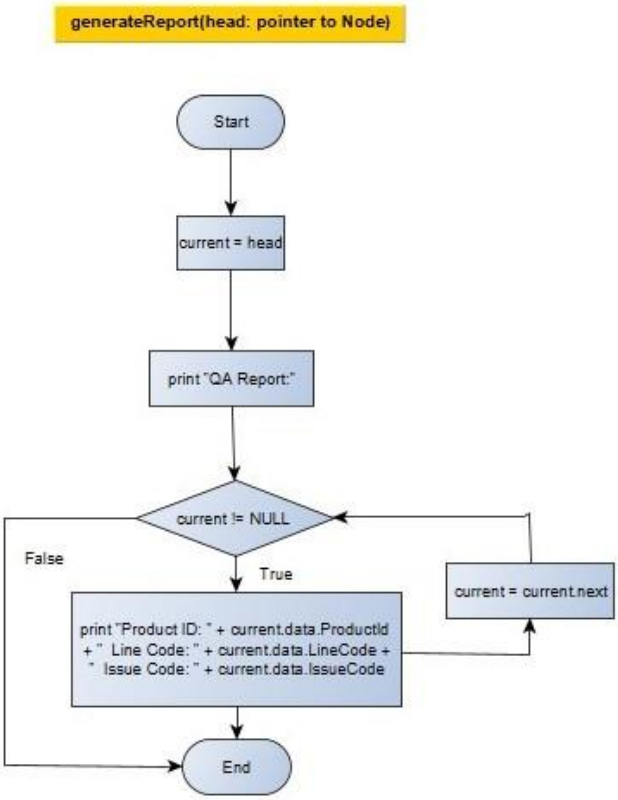
The key functions that have been implemented include the “insertLog” function and the “generateReport” function.

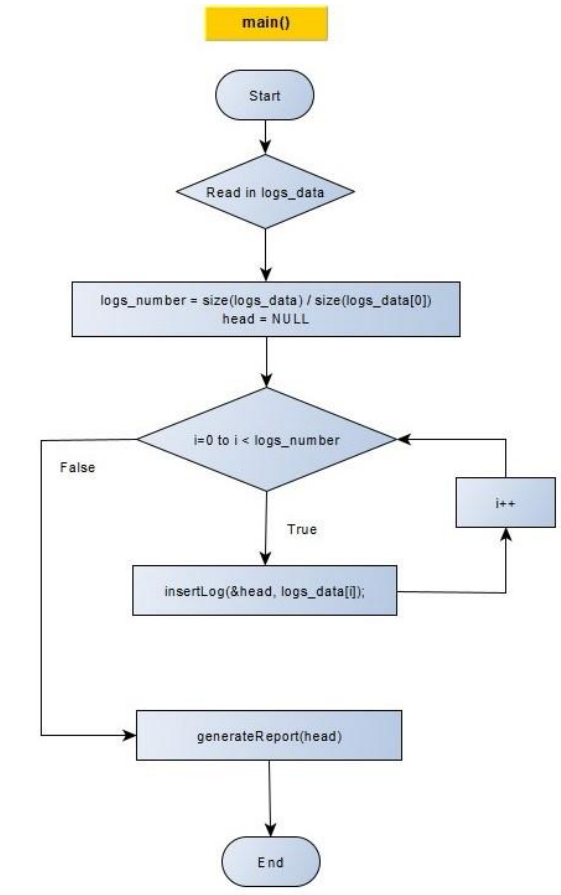
The “insertLog” function is responsible for inserting logs into the linked list while ensuring that they remain in sorted order. This is achieved by allocating memory for a new node, navigating the linked

list to find the correct position for insertion based on Product ID and Line Code, and then inserting the new node at the appropriate position in the linked list.
The “generateReport” function generates and prints the sorted production line report by going through the linked list.

Flowchart




generateReport(head: pointer to Node)
Start
current = head
print "QA Report:"
current != NULL
False
True
current = current.next
print "Product ID: " + current.data.ProductId + " Line Code: " + current.data.LineCode + " Issue Code: " + current.data.IssueCode
End


main()
Start
Read in logs_data
logs_number = size(logs_data) / size(logs_data[0])
head = NULL
i=0 to i < logs_number
False
i++
True
insertLog(&head, logs_data[i]);
generateReport(head)
End

Pseudocode

```
#Function to insert a log into the linked list while maintaining order
based on Product ID and Line Code
Function insertLog(head: pointer to struct Node, struct ProductionLine_Log log)
    #Allocate memory for the new node
    newNode := allocate memory for Node
    if newNode = NULL then
        print ”Memory allocation failed.”
        return
    end if

    #Assign log data to the new node
    newNode.data := log
    newNode.next := NULL

    current := head
    prev := NULL

    #Navigate through the list to find the correct position based on
    Product ID and Line Code
    while current != NULL and (current.data.ProductId <
          newNode.data.ProductId or (current.data.ProductId =
          newNode.data.ProductId and current.data.LineCode <
          newNode.data.LineCode)) do
        prev := current
        current := current.next
    end while

    #Insert newNode at the correct position
    if prev = NULL then
        newNode.next := head
        head := newNode
    else
        prev.next := newNode
        newNode.next := current
    end if
end function


Function generateReport(head: pointer to Node)
    current := head
    print ”Production Line Report:”

    #Print log details
    while current != NULL do
        print ”Product ID: ” + current.data.ProductId + ”  Line Code: ” +
        current.data.LineCode + ”  Issue Code: ” + current.data.IssueCode
        current := current.next
    end while
end function
```

C code

```c
#include <stdio.h>
#include <stdlib.h>
#include <string.h>

// Define DateTime structure
struct DateTime
{
    int dayofmonth;
    int hourofday;
    int minuteofhour;
};

// Define ProductionLine_Log structure
struct ProductionLine_Log
{
    int LineCode;
    int BatchCode;
    struct DateTime BatchDateTime;
    int ProductId;
    int IssueCode;
    char IssueDescription[100];
    int ResolutionCode;
    char ResolutionDescription[100];
    int ReportingEmployeeId;
};

// Define a linked list node for production line logs
struct Node
{
    struct ProductionLine_Log data;
    struct Node *next;
};

/* Function to insert a log into the linked list while maintaining order based on
Product ID and Line Code */
void insertLog(struct Node **head, struct ProductionLine_Log log)
{
    // Allocate memory for the new node
    struct Node *newNode = (struct Node *)malloc(sizeof(struct Node));
    if (newNode == NULL)
    {
        printf("Memory allocation failed.\n");
        return;
    }

    // Assign log data to the new node
    newNode->data = log;
```

```
    newNode->next = NULL;

    struct Node *current = *head;
    struct Node *prev = NULL;

    /* Navigate through the list to find the correct position based on Product ID
    and Line Code */
    while (current != NULL && (current->data.ProductId < newNode->data.ProductId ||
          (current->data.ProductId == newNode->data.ProductId && current->
           data.LineCode < newNode->data.LineCode)))
    {
        prev = current;
        current = current->next;
    }

    // Insert newNode at the correct position
    if (prev == NULL)
    {
        newNode->next = *head;
        *head = newNode;
    } else
    {
        prev->next = newNode;
        newNode->next = current;
    }
}

// Function to generate and print the report
void generateReport(struct Node *head)
{
    struct Node *current = head;
    printf("Production Line Report:\n");

    // Print log details
    while (current != NULL)
    {
        printf("Product ID: %d  Line Code: %d  Issue Code: %d\n", current->
        data.ProductId, current->data.LineCode, current->data.IssueCode);
        current = current->next;
    }
}

int main() {
    // Example ProductionLine_Log array
    struct ProductionLine_Log logs_data[] =
    {
        {1, 101, {1, 20, 45}, 1001, 10, "Defect in wing", 10, "Resolved by replacing
        faulty component", 100},
```

```
        {2, 102, {1, 5, 45}, 1003, 12, "Fire detection system malfunction", 12,
        "Resolved by conducting system testing", 105},
        {5, 105, {1, 11, 45}, 1002, 15, "Engine malfunction", 15, "Resolved by
        replacing affected parts", 102},
        {1, 107, {1, 7, 45}, 1001, 1, "Product damage", 1, "Resolved by adding final
        quality checks", 100},
        {9, 102, {1, 16, 45}, 1003, 3, "Shipping delay", 3, "Resolved by increasing
        number of couriers", 105},
        {6, 103, {1, 23, 45}, 1005, 15, "Engine malfunction", 15, "Resolved by
        replacing affected parts", 102},
        {1, 111, {1, 10, 45}, 1001, 17, "Transportation issue", 17, "Resolved by
        improving transportation methods", 100},
        {3, 116, {1, 6, 45}, 1006, 20, "Customer complaint", 20, "Resolved with
        personalised solutions", 105},
        {1, 109, {1, 22, 45}, 1002, 15, "Engine malfunction", 15, "Resolved by
        replacing affected parts", 102},
        {8, 107, {1, 21, 45}, 1005, 6, "Labelling issue", 6, "Resolved by
        implementing revised labelling procedures", 100},
        {7, 112, {1, 18, 45}, 1001, 12, "Fire detection system malfunction", 12,
        "Resolved by conducting system testing", 105},
        {1, 108, {1, 4, 45}, 1007, 30, "Staff shortage", 30, "Resolved by hiring
        temporary staff", 102},
    };

    int logs_number = sizeof(logs_data) / sizeof(logs_data[0]);

    // Create an empty linked list
    struct Node *head = NULL;

    // Insert logs into the linked list while maintaining order
    for (int i = 0; i < logs_number; i++)
    {
        insertLog(&head, logs_data[i]);
    }

    // Generate and print the report
    generateReport(head);

    return 0;
}
```

TASK 3

The primary aim of this task is to analyse data from different production lines to search for the earliest occurrence of an issue code for a given product ID.

To solve it efficiently, the binary search algorithm is chosen due to its logarithmic time complexity O(Log(N)), which ensures efficient searching even with large datasets.

The “searchEarliestOccurrence” function implements binary search, narrowing the search space through a divide-and-conquer approach. This process repeatedly divides the search interval in half and compares the target value to the middle element, efficiently locating the earliest occurrence while meeting time complexity requirements.

Pseudocode

```
#Binary search function to find the earliest occurrence of issue code for
a product ID
Function searchEarliestOccurrence(struct ProductionLine_Log logs_data[],
logs_number, productID)
    left := 0
    right := logs_number - 1
    earliestIndex := -1

    while left <= right do
        #Calculate mid point
        mid := left + (right - left) / 2

        #Check if the current log matches the productID
        if logs_data[mid].ProductId = productID then
            earliestIndex := mid
            return earliestIndex
        else if logs_data[mid].ProductId > productID then
            right := mid - 1  #Search in the left subarray
        else
            left := mid + 1  #Search in the right subarray

    return earliestIndex
end function
```

C code

```c
#include <stdio.h>

// Define DateTime structure
struct DateTime
{
    int dayofmonth;
    int hourofday;
    int minuteofhour;
};

// Define ProductionLine_Log structure
struct ProductionLine_Log
{
    int LineCode;
    int BatchCode;
    struct DateTime BatchDateTime;
    int ProductId;
    int IssueCode;
    char IssueDescription[100];
```

```
    int ResolutionCode;
    char ResolutionDescription[100];
    int ReportingEmployeeId;
};

/* Binary search function to find the earliest occurrence of issue code for a
product ID */
int searchEarliestOccurrence(struct ProductionLine_Log logs_data[], int logs_number,
int productID)
{
    int left = 0;
    int right = logs_number - 1;
    int earliestIndex = -1;

    while (left <= right)
    {
        // Calculate mid point
        int mid = left + (right - left) / 2;

        // Check if the current log matches the productID
        if (logs_data[mid].ProductId == productID)
        {
            earliestIndex = mid;
            return earliestIndex;
        }
        else if (logs_data[mid].ProductId > productID)
        {
            right = mid - 1;  // Search in the left subarray
        }
        else
        {
            left = mid + 1;  // Search in the right subarray
        }
    }

    return earliestIndex;
}

int main()
{
    // Example ProductionLine_Log array
    struct ProductionLine_Log logs_data[] =
    {
        {1, 101, {1, 20, 45}, 1001, 10, "Defect in wing", 10, "Resolved by replacing
        faulty component", 100},
        {2, 102, {1, 5, 45}, 1003, 12, "Fire detection system malfunction", 12,
        "Resolved by conducting system testing", 105},
        {5, 105, {1, 11, 45}, 1002, 15, "Engine malfunction", 15, "Resolved by
```

```
        replacing affected parts", 102},
        {1, 107, {1, 7, 45}, 1001, 1, "Product damage", 1, "Resolved by adding final
        quality checks", 100},
        {9, 102, {1, 16, 45}, 1003, 3, "Shipping delay", 3, "Resolved by increasing
        number of couriers", 105},
        {6, 103, {1, 23, 45}, 1005, 15, "Engine malfunction", 15, "Resolved by
        replacing affected parts", 102},
        {1, 111, {1, 10, 45}, 1001, 17, "Transportation issue", 17, "Resolved by
        improving transportation methods", 100},
        {3, 116, {1, 6, 45}, 1006, 20, "Customer complaint", 20, "Resolved with
        personalised solutions", 105},
        {1, 109, {1, 22, 45}, 1002, 15, "Engine malfunction", 15, "Resolved by
        replacing affected parts", 102},
        {8, 107, {1, 21, 45}, 1005, 6, "Labelling issue", 6, "Resolved by
        implementing revised labelling procedures", 100},
        {7, 112, {1, 18, 45}, 1001, 12, "Fire detection system malfunction", 12,
        "Resolved by conducting system testing", 105},
        {1, 108, {1, 4, 45}, 1007, 30, "Staff shortage", 30, "Resolved by hiring
        temporary staff", 102},
    };

    int logs_number = sizeof(logs_data) / sizeof(logs_data[0]);

    int productID;
    printf("Enter Product ID to search: ");
    scanf("%d", &productID);

    // Perform binary search for earliest occurrence
    int earliestIndex = searchEarliestOccurrence(logs_data, logs_number, productID);

    if (earliestIndex != -1)
    {
        printf("Earliest occurrence of Product ID %d found at index %d\n",
        productID, earliestIndex);
        printf("Related Issue Code: %d\n", logs_data[earliestIndex].IssueCode);
    }
    else
    {
        printf("Product ID %d not found in logs.\n", productID);
    }

    return 0;
}
```

TASK 4

The primary aim of this task is to efficiently summarise the number of issues reported for a specific product across all production lines. Given the substantial amount of data involved, it is crucial to employ an algorithm with a running time of O(N) or better to ensure optimal efficiency. Considering these requirements, Linear Search emerges as a suitable choice due to its simplicity and effectiveness in counting occurrences within unsorted data. Although Linear Search typically operates with a time complexity of O(N), its structure enables efficient processing of large datasets, meeting this task's time complexity goals. The algorithm goes through each element in the dataset until it finds the target value, which in this case is the specified product ID. By comparing each element's product ID with the target ID and incrementing a counter upon a match, Linear Search ensures that all occurrences of the product ID are counted. The function responsible for implementing the linear search on the provided ProductionLine_Log array is named "countIssues."

Pseudocode

```
#Function to perform linear search and count issues for a product ID
Function countIssues(struct ProductionLine_Log logs_data[], num_logs,
productID)
    count = 0
    for i = 0 to num_logs
        if logs_data[i].ProductId = productID then
            count = count + 1
        end if
    end for
    return count
end function
```

C code

```c
#include <stdio.h>

// Define DateTime structure
struct DateTime
{
    int dayofmonth;
    int hourofday;
    int minuteofhour;
};

// Define ProductionLine_Log structure
struct ProductionLine_Log
{
    int LineCode;
    int BatchCode;
    struct DateTime BatchDateTime;
    int ProductId;
    int IssueCode;
    char IssueDescription[100];
    int ResolutionCode;
```

```
    char ResolutionDescription[100];
    int ReportingEmployeeId;
};

// Function to perform linear search and count issues for a product ID
int countIssues(struct ProductionLine_Log logs_data[], int num_logs, int productID)
{
    int count = 0;
    for (int i = 0; i < num_logs; i++)
    {
        if (logs_data[i].ProductId == productID)
        {
            count++;
        }
    }
    return count;
}

int main()
{
    // Example ProductionLine_Log array
    struct ProductionLine_Log logs_data[] =
    {
        {1, 101, {1, 20, 45}, 1001, 10, "Defect in wing", 10, "Resolved by replacing
        faulty component", 100},
        {2, 102, {1, 5, 45}, 1003, 12, "Fire detection system malfunction", 12,
        "Resolved by conducting system testing", 105},
        {5, 105, {1, 11, 45}, 1002, 15, "Engine malfunction", 15, "Resolved by
        replacing affected parts", 102},
        {1, 107, {1, 7, 45}, 1001, 1, "Product damage", 1, "Resolved by adding final
        quality checks", 100},
        {9, 102, {1, 16, 45}, 1003, 3, "Shipping delay", 3, "Resolved by increasing
        number of couriers", 105},
        {6, 103, {1, 23, 45}, 1005, 15, "Engine malfunction", 15, "Resolved by
        replacing affected parts", 102},
        {1, 111, {1, 10, 45}, 1001, 17, "Transportation issue", 17, "Resolved by
        improving transportation methods", 100},
        {3, 116, {1, 6, 45}, 1006, 20, "Customer complaint", 20, "Resolved with
        personalised solutions", 105},
        {1, 109, {1, 22, 45}, 1002, 15, "Engine malfunction", 15, "Resolved by
        replacing affected parts", 102},
        {8, 107, {1, 21, 45}, 1005, 6, "Labelling issue", 6, "Resolved by
        implementing revised labelling procedures", 100},
        {7, 112, {1, 18, 45}, 1001, 12, "Fire detection system malfunction", 12,
        "Resolved by conducting system testing", 105},
        {1, 108, {1, 4, 45}, 1007, 30, "Staff shortage", 30, "Resolved by hiring
        temporary staff", 102},
    };
```

```c
    int logs_number = sizeof(logs_data) / sizeof(logs_data[0]);

    int productID;
    printf("Enter Product ID to count issues: ");
    scanf("%d", &productID);

    // Perform linear search and count issues for the given Product ID
    int issue_count = countIssues(logs_data, logs_number, productID);

    if (issue_count > 0)
    {
        printf("Number of issues for Product ID %d: %d\n", productID, issue_count);
    }
    else
    {
        printf("No issues found for Product ID %d.\n", productID);
    }

    return 0;
}
```