



NATIONAL UNIVERSITY
of Computer & Emerging Sciences

Parallel and Distributed Computing

Project Report

Warehouse Management

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1. Introduction:

- **Objective:**

To design and implement a Warehouse Management System in C that handles large datasets, processes bulk updates, and provides item management functionalities. The project was further enhanced to include parallel processing using OpenMP and MPI to compare execution times and performance improvements.

- **Scope:**

The system generates warehouse data, stores it in CSV files, and supports functionalities such as data addition, deletion, retrieval, sorting, and more. The performance of single-threaded operations was evaluated and compared against OpenMP and MPI implementations.

2. System Design:

- **Architecture:**

- *Single-Threaded Version*: Handles file operations and data processing using a single thread, focusing on core functionalities like item addition, deletion, and retrieval.
- *OpenMP Version*: Utilizes OpenMP for parallel processing to enhance performance, particularly in bulk updates and inventory calculations.
- *MPI Version*: Implements MPI for distributed processing, where the workload is divided among multiple processors to further reduce execution time.

3. Data Generation:

- **Description:**

A data generation program creates random warehouse data with up to 10 million items and stores them in 20 CSV files for scalability.

- **Data Structure:**

Each item includes attributes such as Item ID, Item Name, Category, Quantity, and Price.

- **Performance:**

Generating the dataset and writing it to CSV files takes significant time, depending on the total number of items and file I/O operations.

4. Functionalities Implemented:

- **Basic Operations:**
 - *Add Item:* Adds a new item to the data set and writes changes to CSV.
 - *Delete Item:* Removes an item based on ID and updates the file.
 - *Retrieve Item:* Retrieves details of an item by ID.
- **Advanced Operations:**
 - *Bulk Update:* Modifies quantities or prices for a set of items.
 - *Search and Sort:* Locates items based on criteria and sorts items by ID or price.
 - *Inventory Analysis:* Calculates the total value of all items in stock.
 - *Low Stock Alert:* Flags items with quantities below a defined threshold.
- **Data Export:**
 - Exports modified data back to CSV for persistence.

5. Parallel Processing Implementations:

- **OpenMP Version:**
 - Utilized `#pragma omp parallel` directives to enable multi-threading.
 - Improved execution speed for operations like bulk updates and inventory analysis by parallelizing loops and data processing tasks.
 - **Execution Time Comparison:**
 - Single-threaded version took significantly longer for processing bulk updates and inventory calculations compared to the OpenMP version.
- **MPI Version:**
 - Divided the dataset among multiple processes using MPI functions like `MPI_Scatter`, `MPI_Gather`, and `MPI_Reduce`.
 - Enabled distributed processing to handle large data more efficiently across multiple nodes.
 - **Execution Time Comparison:**
 - The MPI version showed the most substantial reduction in execution time for large-scale operations due to parallel data handling and reduced communication overhead.

6. Results:

- **Data Generation:**

```
asghar4415@thisisme:/mnt/e/FAST/5th semester/pdc/project/warehouse-management-system/code$ gcc writedata.c -o writedata
asghar4415@thisisme:/mnt/e/FAST/5th semester/pdc/project/warehouse-management-system/code$ ./writedata
Generating data for file warehouse_data_1.csv...
Data written successfully to warehouse_data_1.csv
Generating data for file warehouse_data_2.csv...
Data written successfully to warehouse_data_2.csv
Generating data for file warehouse_data_3.csv...
Data written successfully to warehouse_data_3.csv
Generating data for file warehouse_data_4.csv...
Data written successfully to warehouse_data_4.csv
Generating data for file warehouse_data_5.csv...
Data written successfully to warehouse_data_5.csv
Generating data for file warehouse_data_6.csv...
Data written successfully to warehouse_data_6.csv
Generating data for file warehouse_data_7.csv...
Data written successfully to warehouse_data_7.csv
Generating data for file warehouse_data_8.csv...
Data written successfully to warehouse_data_8.csv
Generating data for file warehouse_data_9.csv...
Data written successfully to warehouse_data_9.csv
Generating data for file warehouse_data_10.csv...
Data written successfully to warehouse_data_10.csv
Generating data for file warehouse_data_11.csv...
Data written successfully to warehouse_data_11.csv
Generating data for file warehouse_data_12.csv...
Data written successfully to warehouse_data_12.csv
Generating data for file warehouse_data_13.csv...
Data written successfully to warehouse_data_13.csv
Generating data for file warehouse_data_14.csv...
Data written successfully to warehouse_data_14.csv
Generating data for file warehouse_data_15.csv...
Data written successfully to warehouse_data_15.csv
Generating data for file warehouse_data_16.csv...
Data written successfully to warehouse_data_16.csv
Generating data for file warehouse_data_17.csv...
Data written successfully to warehouse_data_17.csv
Generating data for file warehouse_data_18.csv...
Data written successfully to warehouse_data_18.csv
Generating data for file warehouse_data_19.csv...
Data written successfully to warehouse_data_19.csv
Generating data for file warehouse_data_20.csv...
Data written successfully to warehouse_data_20.csv
All files generated successfully.
Total time taken: 4.73 seconds
asghar4415@thisisme:/mnt/e/FAST/5th semester/pdc/project/warehouse-management-system/code$ |
```

Data generated of size 10000000 and stored in 20 files.

- **Single Thread Execution:**

```
asghar4415@thisisme:/mnt/e/FAST/5th semester/pdc/project/warehouse-management-system/code$ gcc single_thread.c -o single_thread
asghar4415@thisisme:/mnt/e/FAST/5th semester/pdc/project/warehouse-management-system/code$ ./single_thread
Loading data from warehouse data files...
Data loaded successfully.

===== Warehouse Management System =====
1. Add Item
2. Delete Item
3. Retrieve Item
4. Update Item
5. Process Bulk Updates
6. Search for Item
7. Sort Items by Price
8. View Stock Alerts
9. Print All Items
10. Export Data to CSV
11. View Items by Category
12. Calculate Total Value of All Items
13. Exit
=====
Enter your choice: 12

Total value of all items: 250159693824.00
Processing time: 0.07 seconds
asghar4415@thisisme:/mnt/e/FAST/5th semester/pdc/project/warehouse-management-system/code$ |
```

```
asghar4415@thisisme:/mnt/e/FAST/5th semester/pdc/project/warehouse-management-system/code$ ./single_t
Loading data from warehouse data files...
Data loaded successfully.
```

```
===== Warehouse Management System =====
```

1. Add Item
2. Delete Item
3. Retrieve Item
4. Update Item
5. Process Bulk Updates
6. Search for Item
7. Sort Items by Price
8. View Stock Alerts
9. Print All Items
10. Export Data to CSV
11. View Items by Category
12. Calculate Total Value of All Items
13. Exit

```
=====
```

```
Enter your choice: 5
```

```
Enter increment value for bulk update: 500
```

```
Processing done for 0 items.
```

```
Processing done for 100000 items.
```

```
Processing done for 200000 items.
```

```
Processing done for 300000 items.
```

```
Processing done for 400000 items.
```

```
Processing done for 500000 items.
```

```
Processing done for 600000 items.
```

```
Processing done for 700000 items.
```

```
Processing done for 800000 items.
```

```
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```

```
Processing done for 9600000 items.
```

```
Processing done for 9700000 items.
```

```
Processing done for 9800000 items.
```

```
Processing done for 9900000 items.
```

```
Bulk update completed: Incremented all quantities by 500.  
Total processing time: 300.29 seconds
```

- **Open MP Execution:**

```
asghar4415@thisisme:/mnt/e/FAST/5th semester/pdc/project/warehouse-management-system/code$ gcc -fopenmp -o openmp
asghar4415@thisisme:/mnt/e/FAST/5th semester/pdc/project/warehouse-management-system/code$ ./openmp
Loading data from warehouse data files...
Data loaded successfully.

Warehouse Management System Menu:
1. Add Item
2. Delete Item
3. Retrieve Item
4. Update Item
5. Process Bulk Updates
6. Search Items
7. Sort Items by Price
8. Export Data
9. Stock Alert
10. Print All Items
11. View Items by Category
12. Calculate Total Value
0. Exit

Enter your choice: 12

Total value of all items: 252611526656.00
Processing time: 0.23 seconds
```

```
asghar4415@thisisme:/mnt/e/FAST/5th semester/pdc/project/warehouse-management-system/code$ ./openmp
Loading data from warehouse data files...
Data loaded successfully.
```

Warehouse Management System Menu:

1. Add Item
2. Delete Item
3. Retrieve Item
4. Update Item
5. Process Bulk Updates
6. Search Items
7. Sort Items by Price
8. Export Data
9. Stock Alert
10. Print All Items
11. View Items by Category
12. Calculate Total Value
0. Exit

Enter your choice: 5

Enter increment value for bulk update: 400

Processing done for 5000000 items.

Processing done for 7500000 items.

Processing done for 0 items.

Processing done for 2500000 items.

Processing done for 8800000 items.

Processing done for 6300000 items.

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Processing done for 2400000 items.

Processing done for 7400000 items.

Processing done for 8600000 items.

Processing done for 3700000 items.

Processing done for 6200000 items.

Processing done for 1200000 items.

Processing done for 8700000 items.

Bulk update completed: Incremented all quantities by 400.
Total processing time: 200.53 seconds

- **MPI Execution:**

```
asghar4415@thisisme:/mnt/e/FAST/5th semester/pdc/project/warehouse-management-system/code$ mpicc -o mpi_output mpi_exec.c
asghar4415@thisisme:/mnt/e/FAST/5th semester/pdc/project/warehouse-management-system/code$ ./mpi_output
Loading data from warehouse data files...
Data loaded successfully.

===== Warehouse Management System =====
1. Add Item
2. Delete Item
3. Retrieve Item
4. Update Item
5. Process Bulk Updates
6. Search for Item
7. Sort Items by Price
8. View Stock Alerts
9. Print All Items
10. Export Data to CSV
11. View Items by Category
12. Calculate Total Value of All Items
13. Exit
=====
Enter your choice: 12
Total value of all items: 250159693824.00
```

```
asghar4415@thisisme:/mnt/e/FAST/5th semester/pdc/project/warehouse-management-system/code$ ./mpi_output
Loading data from warehouse data files...
Data loaded successfully.

===== Warehouse Management System =====
1. Add Item
2. Delete Item
3. Retrieve Item
4. Update Item
5. Process Bulk Updates
6. Search for Item
7. Sort Items by Price
8. View Stock Alerts
9. Print All Items
10. Export Data to CSV
11. View Items by Category
12. Calculate Total Value of All Items
13. Exit
=====
Enter your choice: 5
Enter increment value for bulk update: 400

Processing done for 0 items.

Processing done for 100000 items.

Processing done for 200000 items.

Processing done for 300000 items.

Processing done for 400000 items.

Processing done for 500000 items.

Processing done for 600000 items.
```

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```
Processing done for 9400000 items.
Processing done for 9500000 items.
Processing done for 9600000 items.
Processing done for 9700000 items.
Processing done for 9800000 items.
Processing done for 9900000 items.

Bulk update completed: Incremented all quantities by 400.
Total processing time: 200.31 seconds
```

- **Other Funtionalities:**

Retrieve Item:

```
Warehouse Management System Menu:
1. Add Item
2. Delete Item
3. Retrieve Item
4. Update Item
5. Process Bulk Updates
6. Search Items
7. Sort Items by Price
8. Export Data
9. Stock Alert
10. Print All Items
11. View Items by Category
12. Calculate Total Value
0. Exit

Enter your choice: 3
Enter ID of item to retrieve: 19990

Item Details:
ID: 19990
Name: Item_19990
Category: Books
Quantity: 817
Price: 8.02
```

Low stock Alerts:

```
asghar4415@thisisme:/mnt/e/FAST/5th semester/pdc/project/warehouse-management-system/code$ ./openmp
Loading data from warehouse data files...
Data loaded successfully.

Warehouse Management System Menu:
1. Add Item
2. Delete Item
3. Retrieve Item
4. Update Item
5. Process Bulk Updates
6. Search Items
7. Sort Items by Price
8. Export Data
9. Stock Alert
10. Print All Items
11. View Items by Category
12. Calculate Total Value
0. Exit

Enter your choice: 8
```

```

ID: 8581827 | Name: Item_8581827 | Category: Electronics | Quantity: 7 | Price: 80.11
ID: 4103431 | Name: Item_4103431 | Category: Electronics | Quantity: 5 | Price: 44.29
ID: 7901076 | Name: Item_7901076 | Category: Clothing | Quantity: 3 | Price: 42.62
ID: 132891 | Name: Item_132891 | Category: Clothing | Quantity: 4 | Price: 55.76
ID: 6419902 | Name: Item_6419902 | Category: Electronics | Quantity: 7 | Price: 22.50
ID: 5604362 | Name: Item_5604362 | Category: Food | Quantity: 2 | Price: 13.08
ID: 3583118 | Name: Item_3583118 | Category: Electronics | Quantity: 9 | Price: 73.71
ID: 132896 | Name: Item_132896 | Category: Home Goods | Quantity: 2 | Price: 76.77
ID: 1919941 | Name: Item_1919941 | Category: Clothing | Quantity: 8 | Price: 78.18
ID: 4775440 | Name: Item_4775440 | Category: Home Goods | Quantity: 1 | Price: 59.73
ID: 6580772 | Name: Item_6580772 | Category: Food | Quantity: 1 | Price: 80.78
ID: 1919984 | Name: Item_1919984 | Category: Toys | Quantity: 8 | Price: 60.35
ID: 1776987 | Name: Item_1776987 | Category: Books | Quantity: 8 | Price: 36.20
ID: 5400625 | Name: Item_5400625 | Category: Electronics | Quantity: 8 | Price: 67.35
ID: 1920014 | Name: Item_1920014 | Category: Home Goods | Quantity: 9 | Price: 15.43
ID: 8125434 | Name: Item_8125434 | Category: Home Goods | Quantity: 6 | Price: 16.70
ID: 1776994 | Name: Item_1776994 | Category: Food | Quantity: 8 | Price: 47.82
ID: 7420442 | Name: Item_7420442 | Category: Toys | Quantity: 7 | Price: 20.05
ID: 6902456 | Name: Item_6902456 | Category: Books | Quantity: 3 | Price: 93.55
ID: 289589 | Name: Item_289589 | Category: Books | Quantity: 6 | Price: 54.76
ID: 7126245 | Name: Item_7126245 | Category: Home Goods | Quantity: 3 | Price: 17.64
ID: 4103516 | Name: Item_4103516 | Category: Electronics | Quantity: 2 | Price: 11.25
ID: 3583140 | Name: Item_3583140 | Category: Home Goods | Quantity: 9 | Price: 3.47
ID: 4103521 | Name: Item_4103521 | Category: Food | Quantity: 9 | Price: 85.77
ID: 9125663 | Name: Item_9125663 | Category: Electronics | Quantity: 4 | Price: 54.66
ID: 3421605 | Name: Item_3421605 | Category: Electronics | Quantity: 2 | Price: 83.39
ID: 3277534 | Name: Item_3277534 | Category: Electronics | Quantity: 8 | Price: 53.57
ID: 5079087 | Name: Item_5079087 | Category: Books | Quantity: 4 | Price: 23.10
ID: 4775520 | Name: Item_4775520 | Category: Books | Quantity: 6 | Price: 41.19
ID: 5079170 | Name: Item_5079170 | Category: Toys | Quantity: 2 | Price: 99.53
ID: 3126196 | Name: Item_3126196 | Category: Electronics | Quantity: 7 | Price: 57.23
ID: 5400700 | Name: Item_5400700 | Category: Home Goods | Quantity: 7 | Price: 26.14
ID: 2604967 | Name: Item_2604967 | Category: Clothing | Quantity: 4 | Price: 92.07
ID: 7581061 | Name: Item_7581061 | Category: Books | Quantity: 2 | Price: 81.99

```

Many more....

7. Challenges Faced:

- **Synchronization:**

Ensuring consistent data handling in the OpenMP and MPI versions required careful synchronization to avoid race conditions and data inconsistencies.

- **Memory Management:**

Large datasets needed efficient memory allocation, particularly for the MPI version.

- **File I/O Performance:**

Handling large-scale file operations created bottlenecks, requiring optimized read/write methods.

8. Conclusion:

The project successfully demonstrated the effectiveness of parallel processing using OpenMP and MPI to handle large datasets in a Warehouse Management System. The comparison revealed significant performance gains when transitioning from a single-threaded approach to parallel implementations, validating the importance of parallelism in real-world data management.