Stock Market Simulation

1. Introduction

This report analyzes the performance of a parallel flower market simulation using four programming models: **Serial**, **OpenMP**, **MPI**, and a **Hybrid (MPI + OpenMP)** approach. The goal is to evaluate how different parallelization techniques improve execution time and simulate more realistic trading dynamics between buyers and sellers in a competitive market environment.

The simulation models a dynamic trading market where **multiple buyers** attempt to purchase different types of flowers (e.g., roses, tulips, sunflowers) from **multiple sellers**. Each buyer has specific demands and a budget, while each seller has limited stock and price settings. The simulation runs for multiple rounds or until all buyer demands are fulfilled or seller stocks are depleted.

2. Programming Concepts

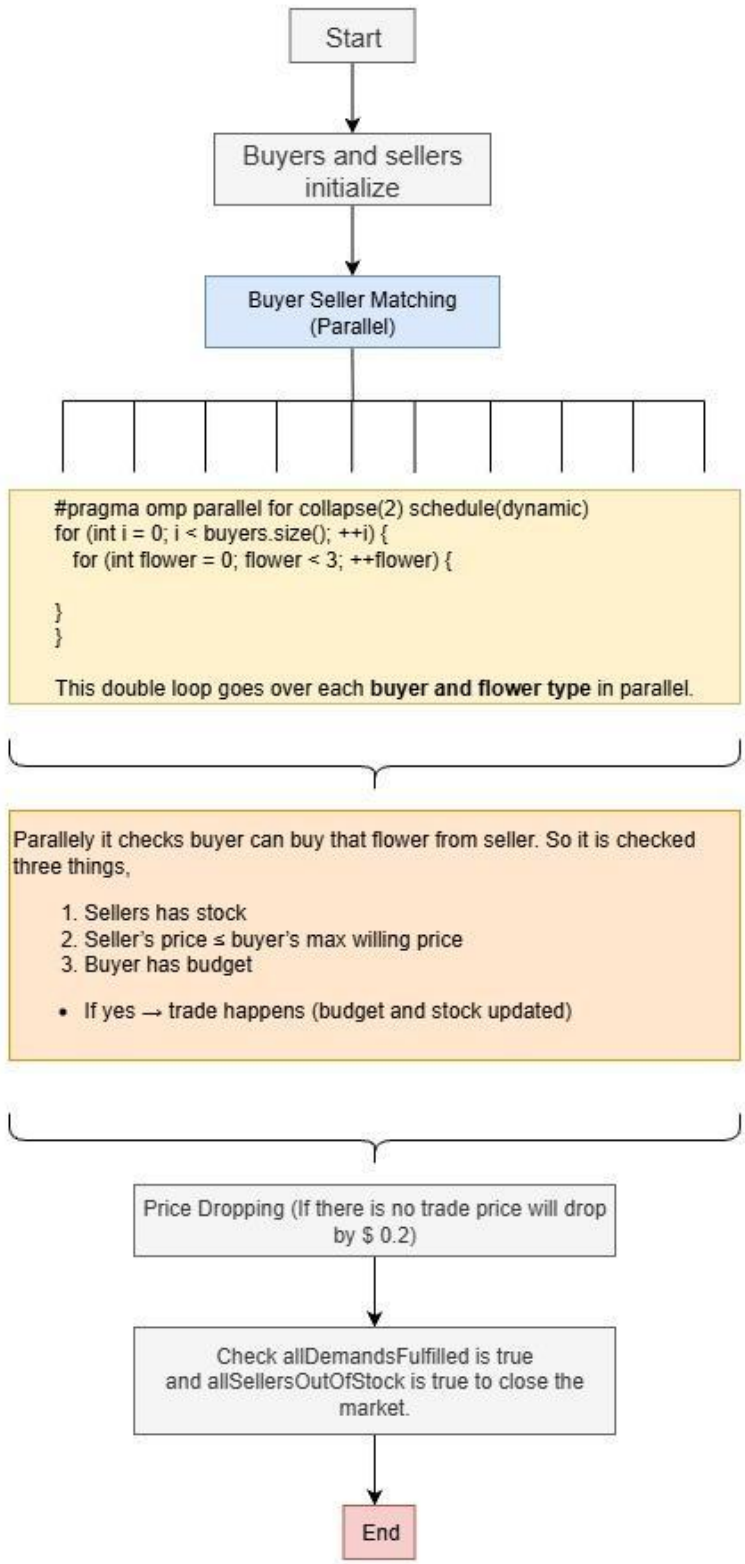
2.1 Serial Approach

In the **serial version**, all buyer-seller interactions are handled by a **single process on one CPU core**. Buyers go through sellers sequentially to purchase flowers based on availability, price, and budget. This version is straightforward but **lacks performance and scalability** for large numbers of buyers and sellers.

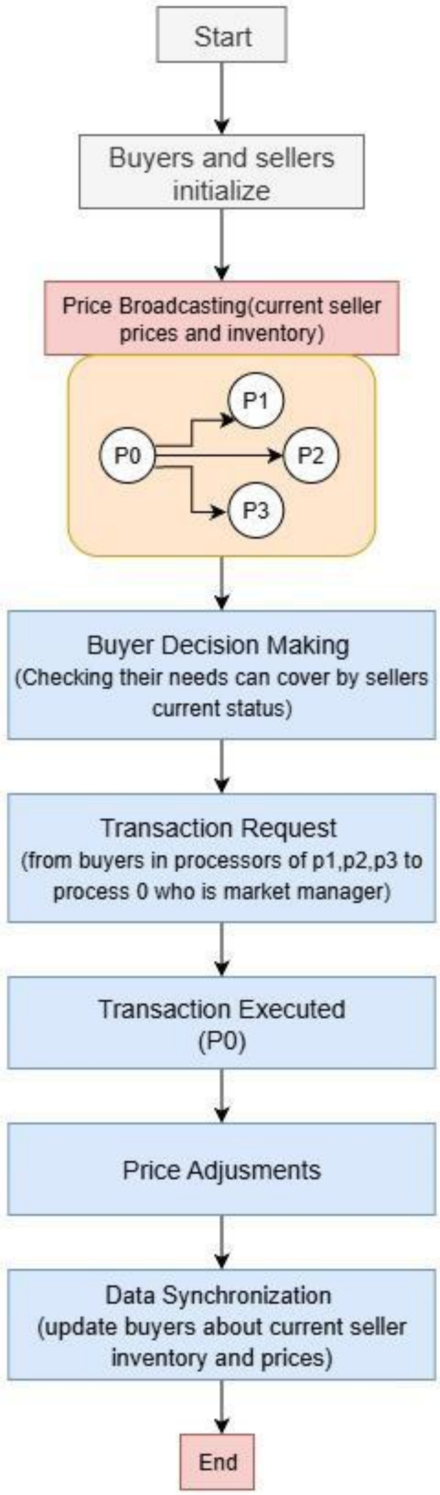
2.2 Shared Memory Programming (OpenMP)

In the **OpenMP version**, the simulation runs as a **single process** using **multiple threads** to exploit shared memory on multicore CPUs. Flower trading operations (e.g., processing each buyer or flower type) are parallelized. This allows:

- Parallel processing of buyers or flower types.
- Reduced simulation time on multicore machines.
- Shared memory access, avoiding explicit communication overhead.


Start
Buyers and sellers initialize
Buyer Seller Matching (Parallel)
#pragma omp parallel for collapse(2) schedule(dynamic)
for (int i = 0; i < buyers.size(); ++i) {
for (int flower = 0; flower < 3; ++flower) {
}
}
This double loop goes over each **buyer and flower type** in parallel.
Parallely it checks buyer can buy that flower from seller. So it is checked three things,
1. Sellers has stock
2. Seller's price ≤ buyer's max willing price
3. Buyer has budget
• If yes → trade happens (budget and stock updated)
Price Dropping (If there is no trade price will drop by $ 0.2)
Check allDemandsFulfilled is true and allSellersOutOfStock is true to close the market.
End

2.3 Distributed Memory Programming (MPI)



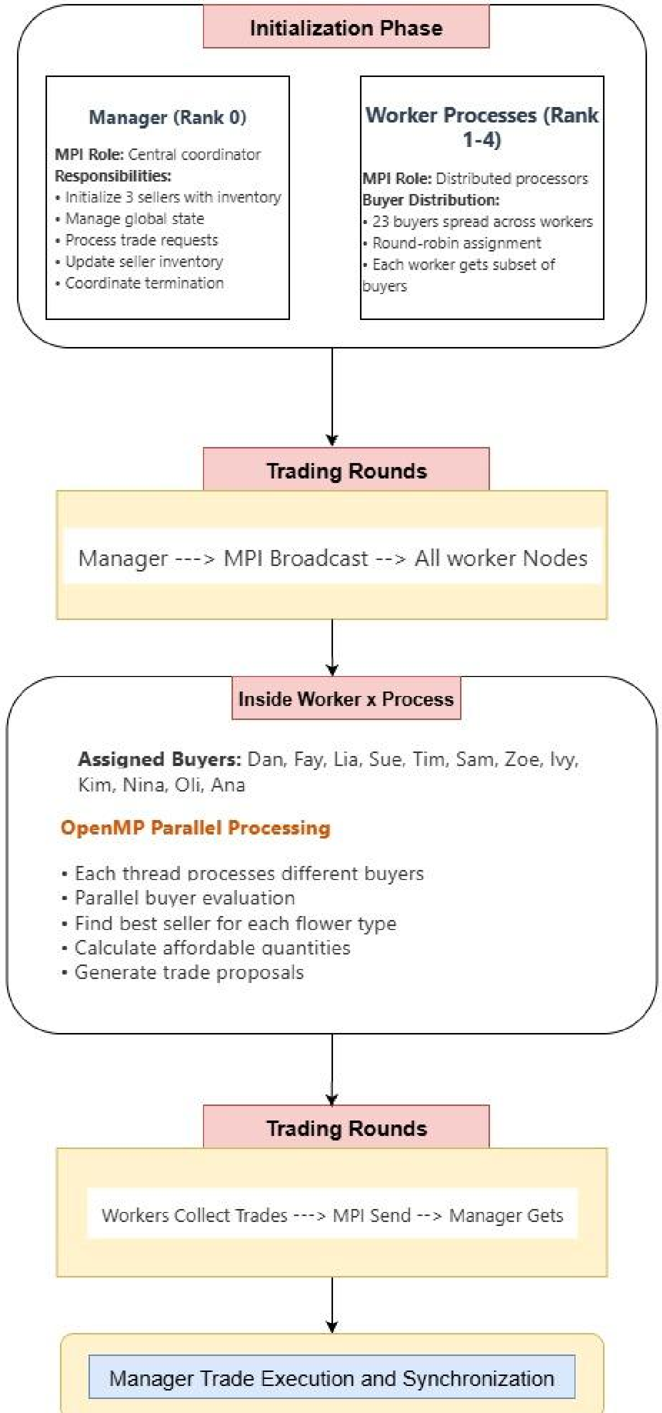
In the **MPI version**, the simulation is **distributed across multiple processes**, which may run on separate CPU cores or machines. Each MPI process is assigned a subset of buyers, while sellers may be centralized or replicated.

MPI is used for:

- Distributing buyer workloads.
- Coordinating seller stock updates.
- Communicating purchase results or boundary market information using "MPI_SendRecv".

This model enables **scalability across clusters or multi-node systems**, though communication overhead must be carefully managed.

2.4 Hybrid Programming (MPI + OpenMP)



The **hybrid approach** combines **MPI** (for inter-process communication and workload distribution) with **OpenMP** (for intra-process thread-level parallelism). For example:

- Each MPI process handles a group of buyers.
- Within each MPI process, OpenMP threads process different flower types or individual buyers concurrently.

3. Accuracy of Parallel Code Compared to Serial Code

3.1 RMSE Calculation

The accuracy of the parallel implementations was measured by comparing their results to the serial code. The **Root Mean Squared Error (RMSE)** was used as a metric to quantify the difference between the parallel and serial methods:

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N} \left(T_{serial}[i] - T_{parallel}[i]\right)^2}$$

The RMSE values were found to be very small for all parallel methods, indicating that the parallel solutions are accurate and the boundary conditions are correctly maintained across the simulations.

Method	**RMSE**
OpenMP	4.55
MPI	9.76
Hybrid	4.33

4. Timing Results

We measured the execution time for each version of the simulation (Serial, OpenMP, MPI, Hybrid).

Method	Time(s)
Serial	19.35
OpenMP	15.2675
MPI	9.76
Hybrid	12.4056

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OpenMP executes times against Number of threads.

Number of Threads	Time(s)
4	15.776
8	15.3044
12	15.2675
16	15.1984