CMPE412 COMPUTER SIMULATION

Manufacturing System

Submitted by:

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Introduction

In this project, we aim to create a computer simulation of the manufacturing life of automotive parts. Initially, we'll focus on making one type of product efficiently and finding any problems that slow down production. The factory will be divided into several parts like handling raw materials, machining, assembling, quality control, inspecting, and packaging the final product. Each part will have its own machines and operators, operating day and night. We examined different scenarios by adjusting variables such as machine count, and shift timing.

Design, Implementation and Analysis

The simulation has different components such as:

- Materials and Products,
- Resources including the Machine and Operator,
- Event and EventQueue to handle the events of the simulation,
- SimulationClock to handle the time of the simulation,
- ProductionStage to handle the manufacturing steps which are ‘Raw Material Handling’, ‘Machining’, ‘Assembling’, ‘Inspecting’, ‘Packaging’.
- UserInput to manage the user inputs,
- ProductType to handle different types of products.

The simulation works in several steps:

```cpp
// Main function
int main() {

    cout << "-----------------------------------------------" << endl;
    cout << "Single Product" << endl;
    cout << "-----------------------------------------------" << endl;

    MultiProductManufacturingSystem system;

    Experimentation experimentation;
    experimentation.runSingleScenarios(system);
    system.showOperationTimes();

    cout << "-----------------------------------------------" << endl;
    cout << "Adjusting variables" << endl;
    cout << "-----------------------------------------------" << endl;

    int machineCount;
    cout << "Input Machine Count: ";
    cin >> machineCount;

    cout << endl;

    int shiftTiming;
    cout << "Input Shift Timing: ";
    cin >> shiftTiming;

    UserInput::getInstance()->setMachineCount(machineCount);
    UserInput::getInstance()->setShiftTiming(shiftTiming);
    experimentation.adjustVariablesAndObserve(system);


    return 0;
}
```

Figure 1 Main function

- Firstly, in the main function, we initialized the manufacturing system which includes the operation types such as RawMaterialHandling, Machining, etc, and also the operators and machines.

```cpp
// Multi-Product Manufacturing System
class MultiProductManufacturingSystem {
private:
    vector<ProductionStage*> stages;
    vector<ProductType> productTypes;
    SimulationClock simulationClock;

public:
    MultiProductManufacturingSystem() {
        stages.push_back(new RawMaterialHandling("Raw Material Handling", simulationClock));
        stages.push_back(new Machining("Machining", simulationClock));
        stages.push_back(new Assembling("Assembling", simulationClock));
        stages.push_back(new Inspecting("Inspecting", simulationClock));
        stages.push_back(new Packaging("Packaging", simulationClock));

        // Create machines and operators
        Machine* machine1 = new Machine("Machine1");
        Machine* machine2 = new Machine("Machine2");
        Operator* operator1 = new Operator("Operator1");
        Operator* operator2 = new Operator("Operator2");

        // Add machines and operators to appropriate stages
        for (auto stage : stages) {
            stage->addMachine(machine1);
            stage->addMachine(machine2);

            stage->addOperator(operator1);
            stage->addOperator(operator2);
        }
    }
```

Figure 2 Manufacturing system

- Then, we initialized an Experimentation object, which will handle the functions of different scenerios such as single product simulation and multiple product simulation. In the first case, we will simulate the single product scenerio.

```
class Experimentation {
public:
    void runSingleScenarios(MultiProductManufacturingSystem& system) {
        system.runSingleSimulation();
        system.analyzeBottlenecks();
        system.showOperationTimes();
    }

    void runMultiScenarios(MultiProductManufacturingSystem& system) {
        system.runMultiProductSimulation();
        system.analyzeBottlenecks();
        system.showOperationTimes();
    }

    void adjustVariablesAndObserve(MultiProductManufacturingSystem& system) {
        runMultiScenarios(system);
    }
};
```

Figure 3 Experimentation Class

- Then, the experimentation will start with default values of machine count and shifting time. The default values are 6 for machine count and 8 for shift timing. According to these values, the total processing time is shown in the Figure 4.

```
-------------------------------------------
Single Product
-------------------------------------------
Processing raw material: Single Material 1 in Raw Material Handling
Machining material: Single Material 1 in Machining
Assembling material: Single Material 1 in Assembling
Inspecting material: Single Material 1 in Inspecting
Packaging material: Single Material 1 in Packaging
Bottlenecks Stage: Raw Material Handling
Bottlenecks Stage: Machining
Bottlenecks Stage: Assembling
Bottlenecks Stage: Inspecting
Bottlenecks Stage: Packaging
Raw Material Handling Time: 0
Machining Time: 0.104167
Assembling Time: 0.0625
Inspecting Time: 0.0208333
Packaging Time: 0.0416667
Total Processing Time: 0.229167
Total Idle Time: -0.229167
-------------------------------------------
```

Figure 4 Single Product with 6 machines and 8 shift timing

- We tried to decrease the machine count to see how the total production time will change. The shifting time remains the same. As we can see in Figure 5, if we decrase the machine count to 3, the total processing time increases. The reason is that, if we

decrease the number of the machines, the workload of each machine increases and this may result in delays in the production.

```
---------------------------------------------
Adjusting variables
---------------------------------------------
Input Machine Count: 3

Input Shift Timing: 8
Processing raw material: Single Material 1 in Raw Material Handling
Machining material: Single Material 1 in Machining
Assembling material: Single Material 1 in Assembling
Inspecting material: Single Material 1 in Inspecting
Packaging material: Single Material 1 in Packaging
Bottlenecks Stage: Raw Material Handling
Bottlenecks Stage: Machining
Bottlenecks Stage: Assembling
Bottlenecks Stage: Inspecting
Bottlenecks Stage: Packaging
Raw Material Handling Time: 0
Machining Time: 0.208333
Assembling Time: 0.125
Inspecting Time: 0.0416667
Packaging Time: 0.0833333
Total Processing Time: 0.458333
Total Idle Time: -0.458333
```

Figure 5 Single Product with 3 machines and 8 shifting time

- After that, we tried to increase the machine count to 9 and keep the shifting time the same. In the Figure 6, we can see that the total processing time decreased. The increased number of machines allows to minimize waiting times, and reduces the workload of each machine. This efficiency leads to faster completion of production stages and overall reduced processing times in the manufacturing process.

```
---------------------------------------------
Adjusting variables
---------------------------------------------
Input Machine Count: 9

Input Shift Timing: 8
Processing raw material: Single Material 1 in Raw Material Handling
Machining material: Single Material 1 in Machining
Assembling material: Single Material 1 in Assembling
Inspecting material: Single Material 1 in Inspecting
Packaging material: Single Material 1 in Packaging
Bottlenecks Stage: Raw Material Handling
Bottlenecks Stage: Machining
Bottlenecks Stage: Assembling
Bottlenecks Stage: Inspecting
Bottlenecks Stage: Packaging
Raw Material Handling Time: 0
Machining Time: 0.0694444
Assembling Time: 0.0416667
Inspecting Time: 0.0138889
Packaging Time: 0.0277778
Total Processing Time: 0.152778
Total Idle Time: -0.152778
```

Figure 6 Single Product with 9 machines and 8 shift timing

- Then, we examined how the shifting time affects the overall process. Firstly, we decreased shift time to 5 and keep machine count the same. In the Figure 7, we see that the total processing time increased. Lower shifting time means less work each day. So, it increases the total processing time.

```
---------------------------------------------
Adjusting variables
---------------------------------------------
Input Machine Count: 6

Input Shift Timing: 5
Processing raw material: Single Material 1 in Raw Material Handling
Machining material: Single Material 1 in Machining
Assembling material: Single Material 1 in Assembling
Inspecting material: Single Material 1 in Inspecting
Packaging material: Single Material 1 in Packaging
Bottlenecks Stage: Raw Material Handling
Bottlenecks Stage: Machining
Bottlenecks Stage: Assembling
Bottlenecks Stage: Inspecting
Bottlenecks Stage: Packaging
Raw Material Handling Time: 0
Machining Time: 0.166667
Assembling Time: 0.1
Inspecting Time: 0.0333333
Packaging Time: 0.0666667
Total Processing Time: 0.366667
Total Idle Time: -0.366667
```

Figure 7 Single Product with 6 machines and 5 shift timing

- After that, we tried to increase the shifting time to 10 and keep machine count the same. As Figure 8 shows, the total processing time decreased. Longer shift time means that the machines will work in longer time and produce more product which leads to the decreasing processing time.

```
---------------------------------------------
Adjusting variables
---------------------------------------------
Input Machine Count: 6

Input Shift Timing: 10
Processing raw material: Single Material 1 in Raw Material Handling
Machining material: Single Material 1 in Machining
Assembling material: Single Material 1 in Assembling
Inspecting material: Single Material 1 in Inspecting
Packaging material: Single Material 1 in Packaging
Bottlenecks Stage: Raw Material Handling
Bottlenecks Stage: Machining
Bottlenecks Stage: Assembling
Bottlenecks Stage: Inspecting
Bottlenecks Stage: Packaging
Raw Material Handling Time: 0
Machining Time: 0.0833333
Assembling Time: 0.05
Inspecting Time: 0.0166667
Packaging Time: 0.0333333
Total Processing Time: 0.183333
Total Idle Time: -0.183333
```

Figure 8 Single Product with 6 machines and 10 shift timing

- The examples above are for the single production. Now, let's look at how multiple production will be affected by the change of the number of machines and shifting time. Let's say that the factory produces Mercedes and they want to produce "C 180", "E 200", and "S 600" products. To examine that, we firstly add these products to manufacturing system in the main function, like in the Figure 9 and then analyse them.

```
MultiProductManufacturingSystem system;

Experimentation experimentation;

cout << "-----------------------------------------------" << endl;
cout << "Multi Product (Mercedes)" << endl;
cout << "-----------------------------------------------" << endl;

system.addProductType(ProductType("C 180", 3.0, { "Raw Material Handling", "Machining", "Assembling", "Inspecting", "Packaging" }));
system.addProductType(ProductType("E 200", 5.0, { "Raw Material Handling", "Machining", "Inspecting", "Packaging" }));
system.addProductType(ProductType("S 600", 4.0, { "Raw Material Handling", "Machining", "Packaging" }));

experimentation.runMultiScenarios(system);
```

Figure 9 Multi-Production

- Like we did in single production, we done the same thing for the multi-production. By default values which are 6 machines and 8 shifting time, the total processing time is shown in Figure 10.

```
-----------------------------------------------
Multi Product (Mercedes)
-----------------------------------------------
Processing product type: C 180
Processing raw material: C 180 in Raw Material Handling
Machining material: C 180 in Machining
Assembling material: C 180 in Assembling
Inspecting material: C 180 in Inspecting
Packaging material: C 180 in Packaging
-----------------------------------------------
Processing product type: E 200
Processing raw material: E 200 in Raw Material Handling
Machining material: E 200 in Machining
Inspecting material: E 200 in Inspecting
Packaging material: E 200 in Packaging
-----------------------------------------------
Processing product type: S 600
Processing raw material: S 600 in Raw Material Handling
Machining material: S 600 in Machining
Machine Machine1 failed during Machining
Packaging material: S 600 in Packaging
-----------------------------------------------
Bottlenecks Stage: Raw Material Handling
Bottlenecks Stage: Machining
Bottlenecks Stage: Assembling
Bottlenecks Stage: Inspecting
Bottlenecks Stage: Packaging
Raw Material Handling Time: 0
Machining Time: 0.104167
Assembling Time: 0.0625
Inspecting Time: 0.0208333
Packaging Time: 0.0416667
Total Processing Time: 0.229167
Total Idle Time: -0.229167
```

Figure 10 Multi-Production with default values

- Then we decreased machine count to 3 and keep shift time the same. Because of the same reasons, the total processing time increased. The workload on each machine increased since the number of machines decreased and it causes higher waiting time.

```
Bottlenecks Stage: Raw Material Handling
Bottlenecks Stage: Machining
Bottlenecks Stage: Assembling
Bottlenecks Stage: Inspecting
Bottlenecks Stage: Packaging
Raw Material Handling Time: 0
Machining Time: 0.208333
Assembling Time: 0.125
Inspecting Time: 0.0416667
Packaging Time: 0.0833333
Total Processing Time: 0.458333
Total Idle Time: -0.458333
```

Figure 11 Multi Product with 3 machines and 8 shifting time

- We increased the machine count to 9 and keep shift time the same. Since we increased the machine count, it caused to reduce the workload of each machine and result in decreased processing time.

```
-------------------------------------------
Bottlenecks Stage: Raw Material Handling
Bottlenecks Stage: Machining
Bottlenecks Stage: Assembling
Bottlenecks Stage: Inspecting
Bottlenecks Stage: Packaging
Raw Material Handling Time: 0
Machining Time: 0.0694444
Assembling Time: 0.0416667
Inspecting Time: 0.0138889
Packaging Time: 0.0277778
Total Processing Time: 0.152778
Total Idle Time: -0.152778
```

Figure 12 Multi Product with 9 machines and 8 shifting time

- Then we examined the effect of decreased shifting time. The shift time reduced to 5 and the machine count remains the same. Since the work time reduced, the machines will produce less product in that time range and require more time to complete the work. This results in the increasing processing time.

```
-------------------------------------------
Bottlenecks Stage: Raw Material Handling
Bottlenecks Stage: Machining
Bottlenecks Stage: Assembling
Bottlenecks Stage: Inspecting
Bottlenecks Stage: Packaging
Raw Material Handling Time: 0
Machining Time: 0.166667
Assembling Time: 0.1
Inspecting Time: 0.0333333
Packaging Time: 0.0666667
Total Processing Time: 0.366667
Total Idle Time: -0.366667
```

Figure 13 Multi Product with 6 machines and 5 shifting time

- Finally, we increased the shifting time to 10 and keep machine count the same. Since the working hours are increased, the machines can produce more products and this results in the decreasing of total processing time.

```
-------------------------------------------
Bottlenecks Stage: Raw Material Handling
Bottlenecks Stage: Machining
Bottlenecks Stage: Assembling
Bottlenecks Stage: Inspecting
Bottlenecks Stage: Packaging
Raw Material Handling Time: 0
Machining Time: 0.0833333
Assembling Time: 0.05
Inspecting Time: 0.0166667
Packaging Time: 0.0333333
Total Processing Time: 0.183333
Total Idle Time: -0.183333
```

Figure 14 Multi Product with 6 machines and 10 shifting time