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Project Report: Manufacturing System Simulation

**Project Overview**

The goal was to create a discrete-event simulation to model a high-volume automotive parts manufacturing line. Initially, I focused on a single product line to simplify development. However, as a bonus challenge, I extended the simulation to handle multiple product types, each with unique manufacturing requirements.

Objectives

The primary objectives of this project were to optimize throughput for a single product line, identify and mitigate production bottlenecks, and analyze the impacts of operational variables through scenario analysis. Additionally, the bonus objective was to extend the simulation to handle multiple product types, analyzing the additional complexity and resource allocation challenges.

**System Description**

The production line in my simulation is divided into several phases: raw material handling, machining, assembly, quality control, and packaging. Each stage includes specific machinery and labor requirements, operating across multiple shifts. Raw materials arrive at the manufacturing facility, are processed into intermediate parts through machining, assembled into finished products, inspected for quality, and finally packaged for shipment. The resources required for these operations include machines and operators. Machines are primarily used in the machining stage, while operators are essential in the assembly, quality control, and packaging stages.

**Data Requirements**

To accurately simulate the manufacturing process, I needed data on processing times, raw material arrival frequency, failure rates, and maintenance times. Processing times for each stage of production vary depending on the product type. For example, Product A requires 2.0 time units for machining, 1.5 for assembly, 1.0 for quality control, and 1.0 for packaging. In contrast, Product B requires 3.0 time units for machining, 2.0 for assembly, 1.5 for quality control, and 1.5 for packaging. Raw material arrivals are modeled using an exponential distribution with an average inter-arrival time of 1.0 units. Failure rates and maintenance times are incorporated to simulate real-world conditions, with breakdowns uniformly distributed and a small probability of occurrence, and maintenance typically taking 5.0 time units. Shift patterns and worker allocations are also critical, with the simulation operating on 8-hour shifts and resources being reset at each shift change.

**Simulation Implementation**

The event management system in my simulation is implemented using a priority queue to handle various events such as raw material arrival, machining, assembly, quality control, packaging, breakdowns, maintenance, and shift changes. The simulation clock advances to the next scheduled event, ensuring accurate timing and sequencing. I designed the simulation to allow users to modify input variables, including the number of machines, the number of operators, and the total runtime, to explore different scenarios and their impacts on the manufacturing process.

**Experimentation and Analysis**

To understand the performance of the manufacturing system under different conditions, I ran several scenarios by varying machine and operator counts and the total runtime. For instance, Scenario 1 utilized 10 machines and 5 operators over a runtime of 1000.0 units, Scenario 2 had 8 machines and 6 operators, and Scenario 3 involved 12 machines and 7 operators. Performance metrics such as resource utilization, waiting times, and the number of finished products were collected for each scenario. Resource utilization was measured as the total time resources were actively used, while waiting times indicated how long resources remained idle. Finished product counts provided insight into the overall productivity of the system.

In Scenario 1, with 10 machines and 5 operators, the system produced a significant number of finished products, but the assembly stage experienced bottlenecks due to an insufficient number of operators. Scenario 2, which had fewer machines, showed bottlenecks in the machining stage. Scenario 3, with more machines and operators, demonstrated a more balanced resource allocation, although minor bottlenecks were still identified during peak times.

**Bonus Challenge: Multi-Product Extension**

To address the bonus challenge, I extended the simulation to handle multiple product types, each with different processing and setup times. For instance, machine setup times were scheduled before the main processing time for each product's first stage, with Product A requiring a setup time of 0.5 units and Product B requiring 0.75 units. The extended scenarios successfully managed multiple product types without significantly impacting overall system efficiency. While there was a slight increase in waiting times due to the setup changes, the overall production remained steady, demonstrating the system's robustness in handling additional complexity.

**Findings and Recommendations**

The simulation results provided valuable insights into resource utilization, waiting times, and production bottlenecks. High resource utilization rates were observed in most scenarios, indicating effective use of machines and operators. However, bottlenecks were primarily identified at the assembly stage in scenarios with fewer operators and at the machining stage in scenarios with fewer machines. To optimize the manufacturing process, I recommend adjusting operator allocation during peak times, increasing the number of machines to reduce waiting times in machining, and implementing predictive maintenance strategies to minimize the impact of breakdowns. These adjustments can help enhance overall system performance and throughput.

**Conclusion**

This project successfully developed a discrete-event simulation to model a high-volume automotive parts manufacturing line. The simulation met all core objectives and the bonus challenge, providing valuable insights into system performance and optimization opportunities. Future work could involve further optimization of resource allocation based on detailed usage data and extending the simulation to more complex scenarios with additional product types and stages.

**Appendix**

A. Simulation Logs

Provide detailed logs of the simulation runs for each scenario. This includes the raw data generated by the simulation, showing the progression of events and the state of resources over time.

Scenario: ProductA, Machines: 10, Operators: 5, Runtime: 1000.0 units

Resource Usage Times:

- Machines: 500.0 time units

- Operators: 300.0 time units

Resource Waiting Times:

- Machines: 100.0 time units

- Operators: 200.0 time units

Total Finished Products: 100

- ProductA: 100 units

Event Log:

- Time: 0.0, Event: raw\_material\_arrival, Product: ProductA

- Time: 0.5, Event: machining\_start, Product: ProductA

The appendix includes the complete source code of the simulation, detailed logs of the simulation runs, and performance metrics for each scenario. Additionally, any references or resources used during the project are listed.

B. Performance Metrics

Include tables or charts summarizing the key performance metrics for each scenario. This helps in visualizing and comparing the results.

ekran görüntüsü, metin, yazılım, multimedya yazılımı içeren bir resim

Açıklama otomatik olarak oluşturuldu