Monty Hall Problem: Complexity Comparison

Overview

Both programs solve the Monty Hall problem but with fundamentally different approaches.

Time Complexity

Bayesian Inference Approach

- **Time Complexity: O(1)** - Constant time
- Performs a fixed number of arithmetic operations regardless of input
- Calculates exact probabilities using Bayes' theorem
- Typical execution time: < 0.000001 seconds

Monte Carlo Simulation Approach

- **Time Complexity: O(n)** - Linear time
- Where n = number of simulations (1,000,000 in this implementation)
- Each simulation involves:
    - Random number generation
    - Conditional checks
    - Counting operations
- Typical execution time: 0.01-0.05 seconds (varies by hardware)

Winner: Bayesian Inference - Orders of magnitude faster

Space Complexity

Bayesian Inference Approach

- **Space Complexity: O(1)** - Constant space
- Uses only a fixed number of double variables
- No data structures or arrays needed
- Memory usage: ~64 bytes (8 doubles)

Monte Carlo Simulation Approach

- **Space Complexity: O(1)** - Constant space
- Uses only a few integer variables for counters
- No arrays or dynamic memory allocation

- Memory usage: ~32 bytes (counters and temporary variables)

Winner: Tie - Both use constant space

Accuracy Comparison

Bayesian Inference

- **Accuracy: Exact (100%)**
- Mathematically precise: 2/3 for switching, 1/3 for staying
- No margin of error

Monte Carlo Simulation

- **Accuracy: Approximate (converges to exact)**
- With 1,000,000 simulations: typically within 0.1% of exact value
- Accuracy improves with $\sqrt{n}$ (law of large numbers)
- Standard error $\approx \sqrt{(p(1-p)/n)} \approx 0.0005$ for n=1,000,000

Winner: Bayesian Inference - Provides exact answers

Advantages & Disadvantages

Bayesian Inference

Advantages:

- Instant results
- Exact probabilities
- No randomness or variance
- Minimal computational resources

Disadvantages:

- Requires mathematical derivation
- Less intuitive for beginners
- Hard to extend to complex variants without rederiving

Monte Carlo Simulation

Advantages:

- Intuitive and easy to understand
- Easy to modify for game variants

- Demonstrates the problem empirically
- Good for educational purposes

Disadvantages:

- Computationally expensive
- Only approximates the answer
- Results vary slightly each run
- Requires many iterations for accuracy