Age of Information Minimization via Dynamic Programming

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https://github.com/BeyzaTurkk/Age-Of-Information

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Abstract

This project explores the optimization of Age of Information (AoI) in communication systems using Dynamic Programming (DP). The simulations evaluate AoI performance under various strategies, considering both perfect and lossy channels. The goal is to analyze how transmission strategies and update decisions influence the freshness of information at the receiver.

1 Introduction

Age of Information (AoI) is a metric that measures the freshness of information at a destination. It is especially relevant in applications such as sensor networks, autonomous systems, and real-time communication. This work investigates how dynamic programming and Monte Carlo simulations can be used to minimize AoI in both ideal and erasure-prone channels.

2 Methodology

The main methodology involves:

- Formulating AoI minimization as a Markov Decision Process (MDP).
- Applying Bellman's equations to compute optimal policies.
- Simulating average AoI via Monte Carlo techniques for various transmission strategies.
- Evaluating performance through plots and comparing strategies under different success probabilities.

Key MATLAB scripts include:

- `bellman_recursive.m`
- `simulate_policy.m`
- `run_aoi_basic_test.m`
- `run_aoi_erasure_test.m`

3 Results

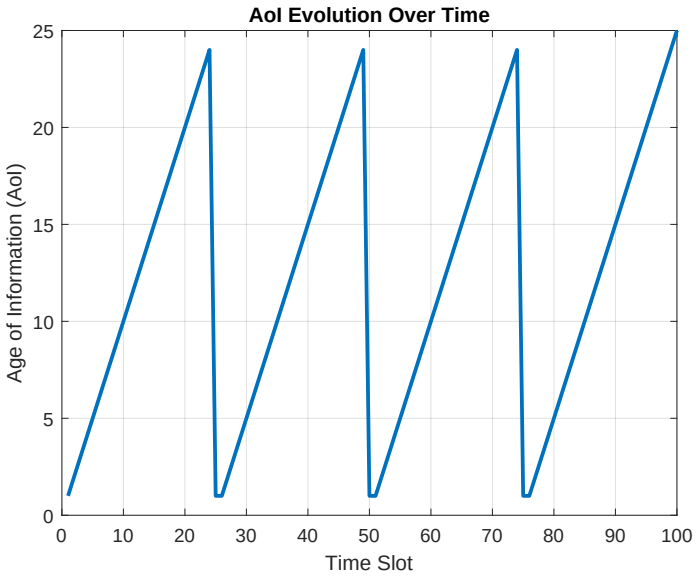

Figure 1: Basic AoI Progression Over Time

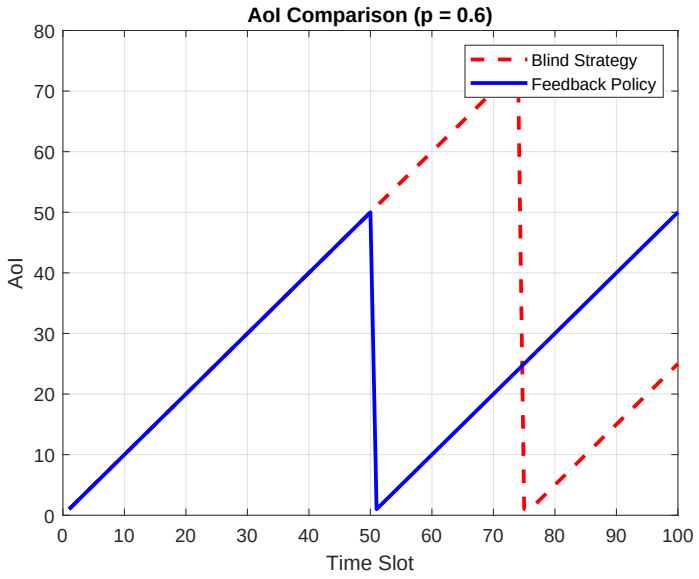

Figure 2: Comparison of AoI Across Different Policies

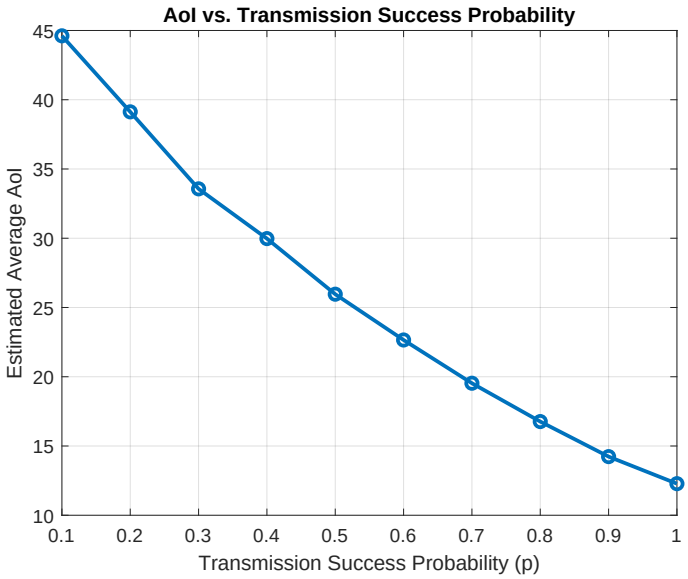

Figure 3: AoI versus Transmission Success Probability

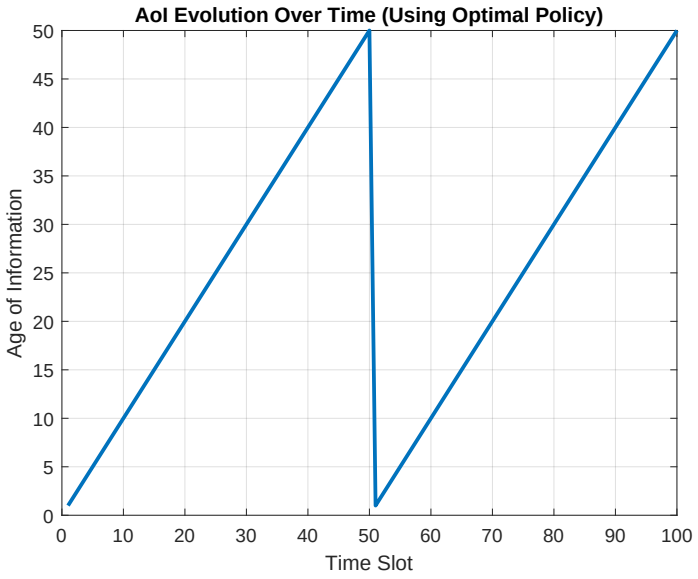

Figure 4: Policy-Based AoI Minimization

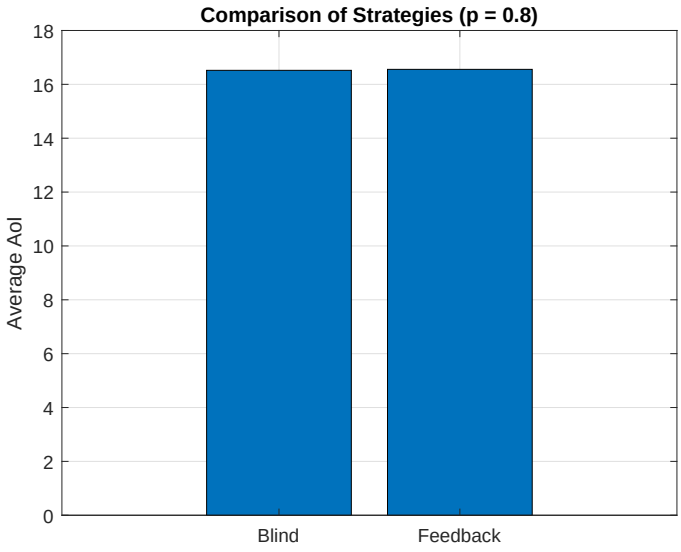

Figure 5: Strategy Comparison on AoI Metrics

4 Conclusion

The results demonstrate how carefully selected update policies can significantly reduce AoI. Dynamic programming provides a structured way to derive optimal policies by modeling system states and transitions. Monte Carlo simulations validate these findings and highlight the influence of erasure probability on AoI performance.