RL-Based Adaptive Filtering for Wireless Signals using PPO

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Motivation

- Wireless signals are corrupted by time-varying noise and interference(AWGA etc.)
- Traditional filters (LMS, RLS, Kalman) assume stationary models(wiener and Kalman good for non-stationary for predefined accurate models.)
- Need for real-time, model-free, adaptive filtering
- Reinforcement Learning (RL), especially PPO, offers a promising solution

Idea

Project Idea

Develop a PPO-based adaptive filtering agent that dynamically adjusts filter parameters to reduce noise in wireless signals in real time.

Literature Survey

- RL in filtering shows promising results in adapting to dynamic environments.
- PPO provides stable training in continuous action spaces.
- Related work: [1, 2, 3, 4, 5, 6, 7]
- **Gap:** Most traditional methods lack real-time learning and generalization.

Papers to Read

- Oh et al., ICC 2021 - RL-based Channel Estimation
- Lin and Lu, CCDC 2023 - PPO for Adaptive Kalman Filtering
- Luo et al., Neural Networks 2024 - DRL for Active Noise Control
- Marino et al., Aerospace 2024 - PPO-integrated Kalman filter
- Li et al., Applied Acoustics 2022 - RL-tuned fractional filters
- et al., - RL-based adaptive kalman filter for ae signal ar mode

Algorithms

- **Proximal Policy Optimization (PPO)**: Stable policy updates, continuous action support
- **Benchmark filters**: LMS, RLS, Kalman
- PPO chosen for real-time, stable adaptation and generalization

RL Framework Design

State: Signal segments, error metrics, filter state
Action: Update filter parameters (e.g., step-size, coefficients)
Reward: Negative MSE or SNR gain
PPO ensures stable training with continuous control capability

Methodology

- Build simulated noisy wireless environment (ns3 - or others)
- Train PPO agent on signal denoising task
- Evaluate against classical LMS, RLS, Kalman filters
- Use DeepMIMO and GNU Radio data (optional - for real testing data)

Evaluation Metrics

- Signal-to-Noise Ratio (SNR)
- Mean Squared Error (MSE)
- Convergence Speed
- Robustness to noise changes

Limitations

- RL training requires large computation and careful reward shaping
- PPO policy inference is heavier than LMS-like filters (M $>$ N where O(M) and O(N)) but better than Kalman or Wiener O(N^3) to O(N^2)
- Generalization to unseen noise types may still require retraining or fine-tuning

Timeline

- Week 1–6: Literature review, setup
- Week 4–7: PPO environment agent
- Week 7–11: Model training
- Week 12: Evaluation
- Week 13: Final report and presentation

Expected Contributions

- Real-time PPO-based adaptive filter
- Quantitative comparison with LMS, RLS, Kalman
- Open-source implementation
- Basis for further research in RL signal processing

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Thank You

Questions?