

# AgentSynth: RL-based Synthetic Data Generator

## Project Report

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### 1. Objective

Design and implement a reinforcement learning agent that learns from a small, structured dataset and generates synthetic data that mimics real-world patterns.

### 2. System Architecture

#### 2.1 Overview

- Uses a custom Gymnasium environment for interaction.
- A Q-learning agent explores action combinations to optimize realism.
- Reward functions score the quality of generated data.

#### 2.2 Components

- SyntheticDataEnvironment: Simulates realistic data generation using tunable factors.
- QLearningAgent: Learns the optimal configuration via iterative exploration.
- AgentSynth: Manages data loading, training, evaluation, and output.

### 3. Methodology

#### 3.1 Dataset

- Simulated e-commerce dataset: user\_id, category, price, quantity, timestamp, total\_revenue
- Categories: Books, Electronics, Furniture, etc.

#### 3.2 Action & Observation Space

- Action: [price\_factor, quantity\_factor, category\_factor, seasonal\_factor]
- Observation: Encoded features including data similarity and progress

3.3 Reward Function

- Price & quantity MSE
- Category distribution similarity
- Revenue similarity

4. Execution

4.1 Training

- 30 episodes, 100 steps each
- Adaptive exploration (epsilon decay)
- Best action tracked

4.2 Data Generation

- Uses best learned parameters
- Applies Gaussian noise for variation

4.3 Validation

- Quantitative metrics: mean, std, distribution differences
- Visualization plots generated

5. Results

5.1 Sample Output

user_id	category	price	quantity	timestamp	total_revenue
-----	-----	-----	-----	-----	-----
1234	Electronics	199.5	2	2024-04-01 14:32:00	399.0
4321	Books	20.4	1	2024-03-15 10:11:00	20.4

5.2 Visual Outputs

- data\_comparison.png
- training\_progress\_YYYYMMDD\_HHMMSS.png

## **6. Challenges and Resolutions**

Challenge: Data distribution mismatch

Resolution: Rebalanced reward weights

Challenge: Import errors with Gym

Resolution: Used gymnasium

Challenge: Poor exploration

Resolution: Added epsilon decay and noise control

## **7. Learnings**

- RL is highly effective in structured data simulation when reward functions are carefully designed.
- Simple agents like Q-learning can deliver strong performance.
- Visualization and distribution matching are essential to validate synthetic data quality.

## **8. Conclusion**

AgentSynth successfully demonstrates how reinforcement learning can be applied to generate high-quality synthetic data, adapting to contextual scenarios and simulating diverse user behaviors.