KLunar Navigator: AI for Lunar Exploration

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Project Overview

The KLunar Navigator is an AI-driven rover navigation system for lunar exploration, utilizing Q-learning to autonomously navigate a 10x10 grid from a start point (0,0) to a target (9,9) while avoiding obstacles.

Objectives

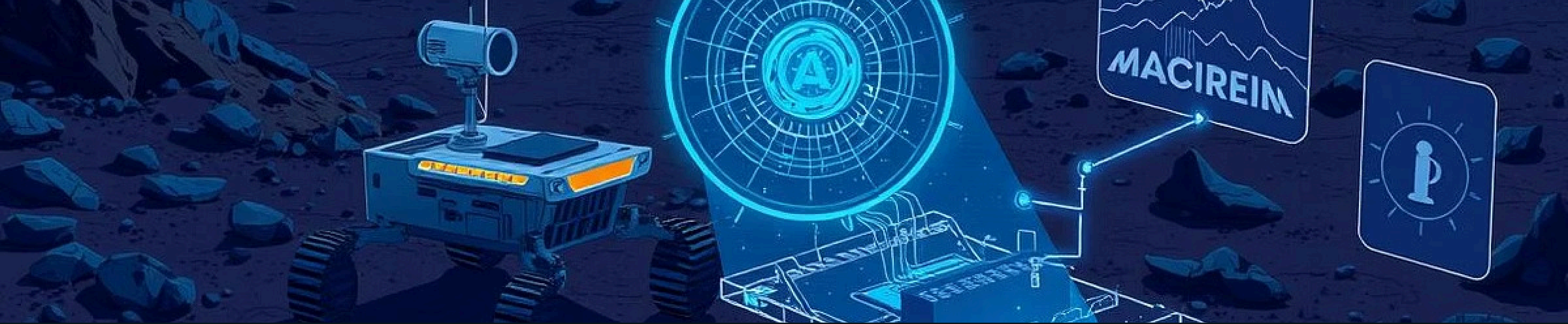
- Develop a functional Q-learning agent.
- Create a Pygame-based visualization.
- Ensure robustness against obstacles.
- Prepare for scalability.

Benefits

- Enhances RL understanding in robotics.
- Provides a testable prototype.
- Supports educational outreach.

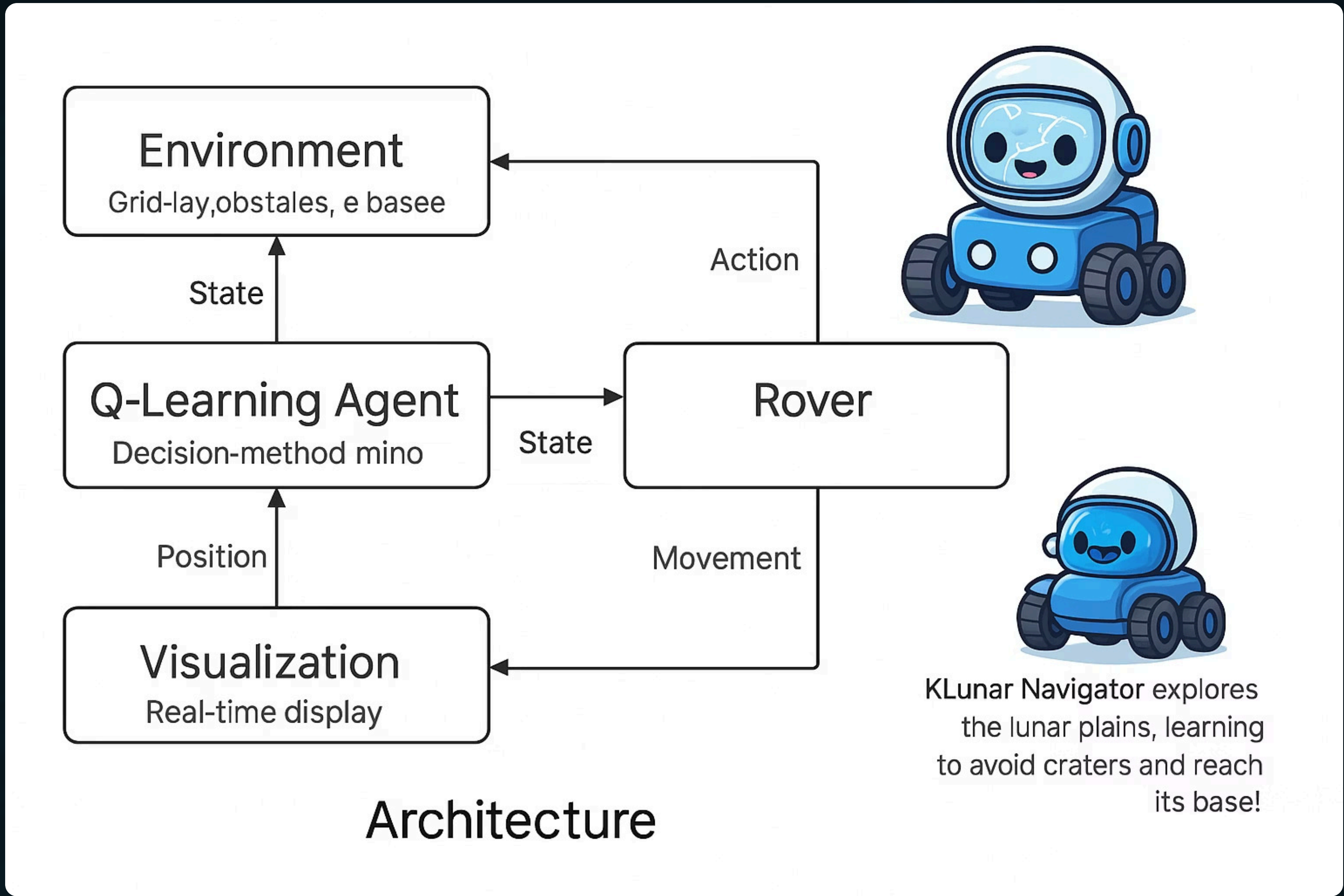
KLunar Navigator

explores the lunar plains,
learning to avoid craters
and reach its base.



System Architecture

The system integrates several key components: LunarEnvironment, Rover, QLearningAgent, and Visualizer, all managed by a main loop for autonomous navigation and real-time feedback.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Q-Learning Agent
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State
Rover
Position
Movement
Visualization
Real-time display
KLunar Navigator explores the lunar plains, learning to avoid craters and reach its base!
Architecture

Solution Approach: Core Components

Environment Setup

10x10 grid with start (0,0), target (9,9), and random obstacles.

Rover Movement

Four actions (right, left, down, up) with energy tracking and boundary checks.

Q-Learning Agent

Q-table for 10x10x4 states, learning from rewards and saving data.

Visualization

Pygame window rendering rover, target, and obstacles in real-time.

Technical Details & Main Loop

Main Loop (main.py)

- 100 episodes, 200 max steps per episode.
- Manages setup, loop, and Q-table persistence.

Optimizations

- Reduced obstacles for faster convergence.
- Adjusted learning parameters.
- Max_steps ensures loop completion.

The system is built with Python 3.12, utilizing Pygame, NumPy, and asyncio libraries for efficient simulation and visualization.

Testing Plan: Validation Objectives

Validate the rover's ability to navigate from (0,0) to (9,9), avoid obstacles, and complete 100 episodes within 200 steps each.

1. **Initial Movement**

   Verify correct movement and reward for basic actions.

2. **Obstacle Avoidance**

   Confirm rover stays at current position with negative reward.

3. **Target Reach**

   Ensure target reached with positive reward and episode termination.

4. **Boundary Check**

   Test edge cases to confirm rover stays within grid.

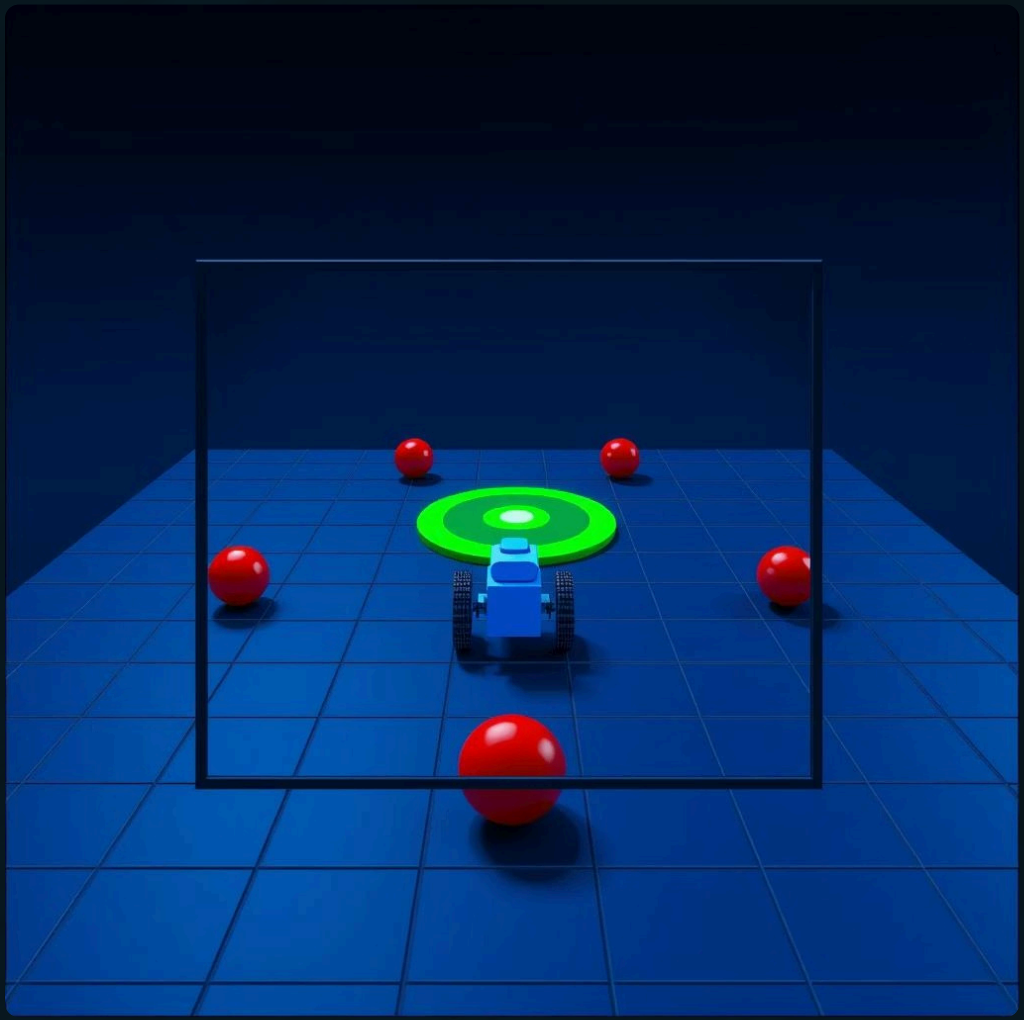
Testing Success Criteria

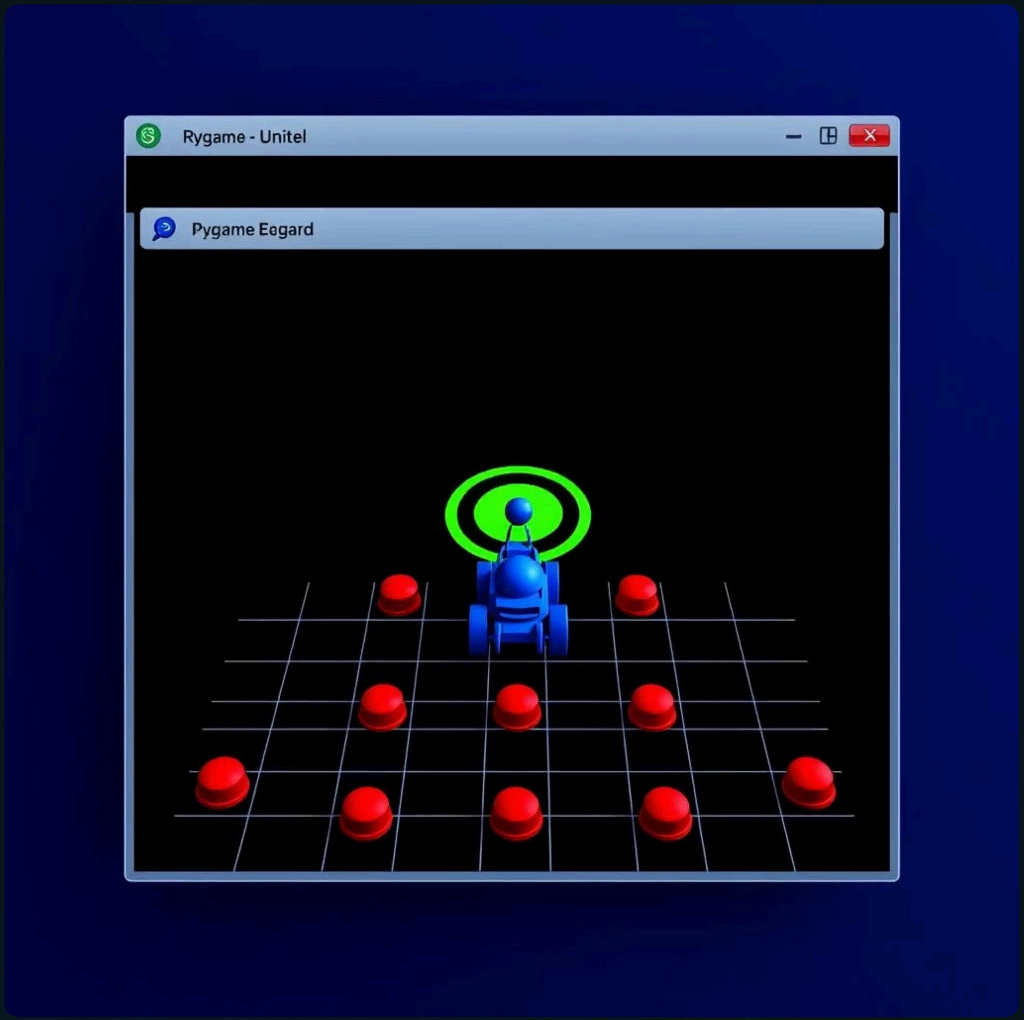
Visual Confirmation

Rover moves visibly toward (9,9) in Pygame.

Episode Completion

100 episodes complete within 20,000 total steps.





A generated q_table.npy with non-zero values confirms successful learning.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Future Enhancements

Dynamic Obstacles

Implement real-time obstacle generation for complex scenarios.

Multi-Rover Coordination

Develop algorithms for multiple rovers to cooperate.

3D Terrain Simulation

Upgrade visualization and navigation to a realistic 3D environment.

These enhancements will further bridge the gap between conceptual simulation and real-world space exploration.