CSE440

Project: Autonomous-Exploration-System-for-Simulated-Volcanic-Terrain-Using-Markov-Decision-Process-MDP
Group: 5
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Introduction:

This project aims to develop an Autonomous Exploration System for navigating and exploring hazardous environments, such as a volcanic field. The system will use Markov Decision Processes (MDP) and Reinforcement Learning (RL) to optimize navigation while ensuring safety.

Work Progress:

Our team consists of **four members**, and we have completed the following tasks so far:

- **Team Formation**: A group of four members has been established.
- **GitHub Repository Creation**: We have set up a GitHub repository to manage our project's code and documentation.
- **Repository Enhancement**: Currently, we are working on improving the repository to meet our faculty's requirement by refining its structure, adding documentation, and maintaining clear version control.

About Our Project:

The **Autonomous Exploration System** aims to develop an intelligent agent capable of navigating and exploring hazardous environments, such as **volcanic fields**, while ensuring safety and efficiency. Using **Markov Decision Processes (MDP)** and **Reinforcement Learning (RL)**, the system will make optimal decisions to explore new areas, avoid dangers like gas emissions and lava flows, and maximize rewards. This project integrates advanced **AI techniques** to enhance real-world applications in exploration, robotics, and disaster response.

- **Environment Definition:** The system navigates a grid-based terrain with dynamic elements such as gas emissions, lava flows, and designated exploration targets.
- **MDP Components:**
    - **States:** Capturing agent position, gas concentration, lava presence, and the exploration map.
    - **Actions:** Movement in four cardinal directions, staying in place, and sensing hazards.

- **Transition Probabilities:** Implementing probabilistic movement, gas dynamics, and lava flow variations.
  - **Rewards:** Encouraging exploration while penalizing hazardous interactions.
- **Policy Design:** The policy aims to maximize cumulative rewards by prioritizing unexplored regions while avoiding hazards.
- **Solution Approach:**
  - Implemented **Value Iteration** to derive an optimal policy for decision-making.
  - Incorporated **Reinforcement Learning (Q-learning, DQN)** for environments where transition probabilities are unknown.
- **Safety Mechanisms:**
  - Hazard avoidance strategies to prevent high-risk moves.
  - Predefined escape routes and safe zones.
  - Energy management to optimize efficiency and longevity.
- **Simulation and Testing:**
  - Implemented in a simulated grid-based environment using Python.
  - Evaluated using metrics like exploration efficiency, safety compliance, and energy consumption

Future work progress plan:

To execute the next phase of our project, we will be utilizing the following tools and libraries:

1. **NumPy**
   - Used for numerical computations, matrix operations, and handling state transitions.
   - Installation: `pip install numpy`
2. **SciPy**
   - Provides advanced mathematical functions and optimization tools, including methods to solve the **Markov Decision Process (MDP)**.
   - Installation: `pip install scipy`
3. **OpenAI Gym**
   - A toolkit for developing and testing **reinforcement learning** algorithms. It will be used to create a custom environment that simulates the **volcanic field**.
   - Installation: `pip install gym`

These tools will allow us to model the **volcanic field**, define **agent behavior**, implement **reinforcement learning algorithms**, and simulate the exploration process effectively.

Conclusion:

The project is progressing as planned, with foundational elements in place. Moving forward, we will focus on implementing key algorithms and refining our system to achieve optimal exploration performance.