Project Report: Optimization of HCAS Using MDP and Q-Table Analysis

Objective:
The primary goal of this project was to optimize an aircraft collision avoidance system (Horizontal Collision Avoidance System, HCAS) using a Markov Decision Process (MDP) framework. The focus was on translating the HCAS MDP implementation from Julia to Python, analyzing its functionality, and improving the output Q-table distribution by tuning input parameters.

Phase 1: Translation and Analysis

1. **Julia to Python Translation:**
    - The original HCAS MDP code, written in Julia, relied on outdated libraries that were difficult to locate or no longer supported. Reproducing the code in Python required addressing these compatibility issues while maintaining the original functionality.
2. **Q-Table Distribution Analysis:**
    - The initial Q-table distribution was heavily skewed, with 70% of the actions favoring "do nothing" and the remaining 30% split between "WL" (weak left), "WR" (weak right), "SL" (strong left), and "SR" (strong right). This imbalance prompted the need for adjustments to ensure a more uniform distribution of approximately 20% for each action.
3. **Input Parameter Tuning:**
    - Inputs, provided in polar coordinates, were modified to achieve a better distribution of output actions. Parameters such as `psi` (relative heading), `theta` (angular position), and the sampling distance were adjusted.
    - Observations showed that a larger difference between the best and worst action values in the Q-table correlated with more critical situations (e.g., higher collision probabilities). Identifying these scenarios helped refine the input parameters to balance the Q-table distribution.

Phase 2: Modifications and Results

1. **Key Adjustments:**
    - Modified `psi`, `theta`, and sampling distances to reduce skewness in the Q-table.
    - Ensured that critical situations (e.g., when aircraft were closer or heading into potential collision paths) were better represented in the action distribution.
2. **Q-Table Optimization:**
    - The final Q-table displayed a more balanced distribution, reducing the dominance of the "do nothing" action and ensuring more equitable representation of all possible actions.
3. **Critical Situations Analysis:**
    - By analyzing maximum and minimum Q-values across rows and studying their standard deviations, critical moments were identified and their distributions examined. This allowed the system to adjust constants dynamically based on critical scenarios.

Simulations:
Although full simulations with aircraft trajectories were considered, they were not implemented in the final phase. Future work could involve testing the optimized Q-tables in simulated environments to validate their performance.

Conclusion:
This project successfully translated the HCAS MDP from Julia to Python and improved the Q-table action distribution by tuning polar-coordinate inputs. The refined system demonstrates a more balanced decision-making process, which could potentially enhance collision avoidance capabilities. Future steps include simulation-based validation and exploration of alternative reward systems to further improve the MDP's performance.