Artificial Intelligence Lab

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Lab. Test-I

Problem Description

You are tasked with designing a genetic algorithm code in python to optimize the docking maneuver of a small three-engines spacecraft into a larger mothership in space. While docking, the spacecraft stops its two side engines and must adjust its main central engine force to achieve a smooth and precise docking. The engine force can be controlled by multiple parameters, and the goal is to find the optimal combination of these parameters to minimize docking error and fuel consumption while ensuring the safety of the spacecraft.

Figure 1: single-engine spacecraft performing a precise docking maneuver with the mothership in deep space.

Objective Function

The objective is to minimize the following cost function:

$$\textbf{Cost} = w_1 \cdot \textbf{Docking Error} + w_2 \cdot \textbf{Fuel Consumption} + w_3 \cdot \textbf{Safety Penalty}$$

[*]Amygdala AI, is an international volunteer-run research group that advocates for *AI for a better tomorrow* http://amygdalaai.org/.

Where:

- **Docking Error**: The Euclidean distance between the spacecraft's final position and the target docking position.
- **Fuel Consumption**: The total amount of fuel used during the docking maneuver.
- **Safety Penalty**: A penalty term that increases if the spacecraft comes too close to the mothership or exceeds safe velocity limits.
- w_1, w_2, w_3: Weights that balance the importance of docking error, fuel consumption, and safety.

Parameters and Their Ranges

The engine force is controlled by the following parameters, each with a specified range:

- **Thrust Magnitude (F)**: The force applied by the engine.
$$0 \leq F \leq F_{\max} \quad (\text{e.g., } 0 \leq F \leq 1000\,\text{N})$$
- **Thrust Angle (θ)**: The angle of the thrust vector relative to the spacecraft's current velocity vector.
$$-180^\circ \leq \theta \leq 180^\circ$$
- **Burn Duration (t)**: The duration for which the engine is fired.
$$0 \leq t \leq t_{\max} \quad (\text{e.g., } 0 \leq t \leq 60\,\text{seconds})$$
- **Time of Ignition (t_{ign})**: The time at which the engine is fired relative to the start of the maneuver.
$$0 \leq t_{\text{ign}} \leq t_{\text{total}} \quad (\text{e.g., } 0 \leq t_{\text{ign}} \leq 120\,\text{seconds})$$

Constraints

- **Final Position Constraint**: The spacecraft must dock within a specified tolerance of the target position.
$$\text{Docking Error} \leq \epsilon \quad (\text{e.g., } \epsilon = 0.1\,\text{meters})$$
- **Velocity Constraint**: The spacecraft's final velocity relative to the mothership must be below a safe threshold.
$$|v_{\text{final}}| \leq v_{\text{safe}} \quad (\text{e.g., } v_{\text{safe}} = 0.5\,\text{m/s})$$
- **Fuel Constraint**: The total fuel consumption must not exceed the spacecraft's fuel capacity.
$$\text{Fuel Consumption} \leq \text{Fuel}_{\max}$$
- **Safety Constraint**: The spacecraft must maintain a minimum distance from the mothership at all times.
$$\text{Minimum Distance} \geq d_{\text{safe}} \quad (\text{e.g., } d_{\text{safe}} = 10\,\text{meters})$$

This solution would result in a low docking error, minimal fuel consumption, and adherence to all safety constraints.