Task 3

Report

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Indice

1 Implementation

This project focused on understanding and applying various potential fields in the creation of motor schemas for robotics.

Initially, two motor schemas were implemented and tested separately:

1. **Attraction to the light source:** this behavior makes the robot move towards the light source and stay close to it.
   - **Potential force field:** attractive field.
   - **Vector calculation:** the attractive force is inversely proportional to the distance from the light source.
2. **Obstacle avoidance:** this behavior prevents the robot from colliding with obstacles such as walls, boxes, and other robots.
   - **Potential force field:** repulsive field.
   - **Vector calculation:** the repulsive force is inversely proportional to the distance from the obstacle.

1.1 Issues Encountered

During the simulations, several issues were observed:

- **Slow movement initiation:** the robot was very slow to start moving when it began from a great distance from the force sources.
- **Stagnation in the absence of dominant forces:** if the robot was far from both the light and the obstacles, it tended to remain stationary.
- **Getting stuck in local minima:** the robot sometimes got stuck in corners or parts of the arenas, remaining trapped in local minima.

1.2 Solutions Implemented

To address these issues, the following solutions were implemented:

1. **Added Noise:** to reduce the problem of local minima, noise was introduced to the forces. This noise, adjustable via the `NOISE_FACTOR` hyperparameter, adds small random vectors to the final movement vector.
   - **Vector calculation:** small random vector add to the final movement vector.

2. **Uniform Force Field:** to improve movement speed, a uniform force field was implemented that allowed the robot to move even in the absence of other forces, thus increasing its reaction speed. This uniform force field is combined with other forces for smoother movement.
    - **Potential force field:** uniform field.
    - **Decay of Uniform Force:** to improve movement speed, a uniform force field was implemented that allowed the robot to move even in the absence of other forces, thus increasing its reaction speed. This uniform force field is combined with other forces for smoother movement.
3. **Avoidance of Past Positions:** to prevent the robot from getting stuck in a loop, a repulsive field from past positions was implemented. This behavior also avoids oscillations between two positions.
    - **Potential force field:** repulsive field from past positions.
    - **Vector calculation:** similar to obstacle avoidance, but with past positions stored in memory.

1.3 Additional Behaviors

Various behaviors were experimented with by combining existing forces:

- **Aggressive behavior:** high attraction to the light and strong repulsion from obstacles make the robot faster and more aggressive.
- **Exploratory behavior:** attraction to light and a combination of attraction&repulsion from obstacles improve obstacle avoidance efficiency creating a obstacle following behaviour.

The exploration aims to reflect, at least in part, the **random wandering** implemented in previous labs, adding a more structured exploratory behavior.

A condition based on the light threshold (`LIGHT_THRESHOLD`) was added to switch between aggressive and exploratory behavior, adjustable via the `AGGRESSIVE_INTENSITY_MULTIPLIER` and `EXPLORE_INTENSITY_MULTIPLIER` hyperparameters.

1.4 Hyperparameter Management

All hyperparameters used in the project have been extracted into a configuration file named `config.lua`. This approach allows for easier modification, facilitating **optimization and permit to experiment with different sets of parameters**.

2 Performance Analysis

To improve the **reproducibility** of simulations, the testing script was enhanced using an Argos template file to **generate simulations with different seeds**. This improved result analysis and reduced outliers. Although parameters were adjusted manually, further exploration of hyperparameter ranges could optimize results.

First approach was a analysis of **300 simulations** with **3000 steps** (Figure 1) showing significant improvement compared to previous tasks. The greater distribution under value 2 is due to the uniform force and aggressive behavior.

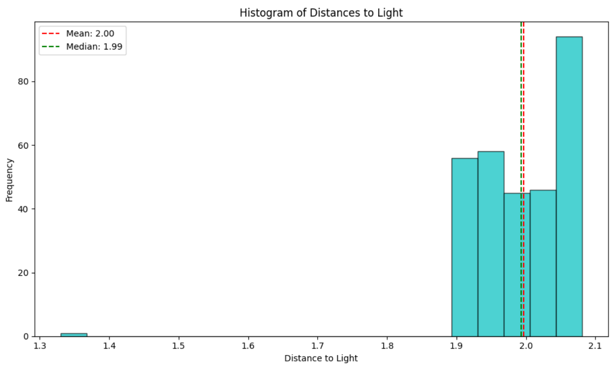

Figura 1: Histogram of Distances to Light

A second analysis was **Mann-Whitney U test** conducted to compare the ‘DistanceToLight‘ values between two groups of simulations classified by even and odd seed numbers, to determine if there was a significant difference between these groups.

Tabella 1: Mann-Whitney U Test Results

Group	Simulations	DistanceToLight (Mean)
Even Seeds	1500	1.85
Odd Seeds	1500	1.87

- **Mann-Whitney U Test Statistic:** 1154584.0
- **P-value:** 0.2115635411974347

The p-value is greater than the typical significance level ($\alpha = 0.05$), indicating that we **fail to reject the null hypothesis for this samples**. Thus, there is no significant difference in the ‘DistanceToLight‘ distributions between simulations with even and odd seed numbers. This suggests that any observed differences are likely due to random variation rather than a significant underlying effect of the seed number.

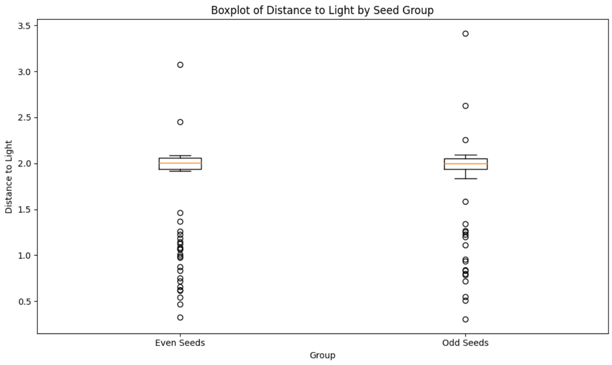

Figura 2: Boxplot of Distance to Light by Seed Group

3 Conclusions & Toughts

Addressing issues such as slow movement initiation, stagnation, and getting stuck in local minima improved the robot’s performance. Adding **noise reduced the likelihood of getting stuck in local minima**, while the **uniform force field improved initial speed and reduced the steps to reach the light** (approximately 2500). **Exploratory behavior enhanced navigation** around obstacles.

- The Motor Schema architecture offers **flexibility** and **modularity**, excelling in environments that require **high reactivity**. However, it presents challenges in behavior coordination and complex behaviours.
- Conditional activation and prioritization can improve **flexibility, efficiency**, and **behavior coordination**. A hybrid architecture combining MS and subsumption architectures could leverage the strengths of both, offering a robust, flexible, and extendible behavior control system.
- A possible improvement could involve further tuning of hyperparameters and exploring additional behaviors to enhance the robot’s capabilities.