Evolving a Simple Gait for a Bipedal Robot

The **core idea** is to use a genetic algorithm within a physics simulation (Webots) to evolve a functional and efficient walking behavior for a two-legged robot.

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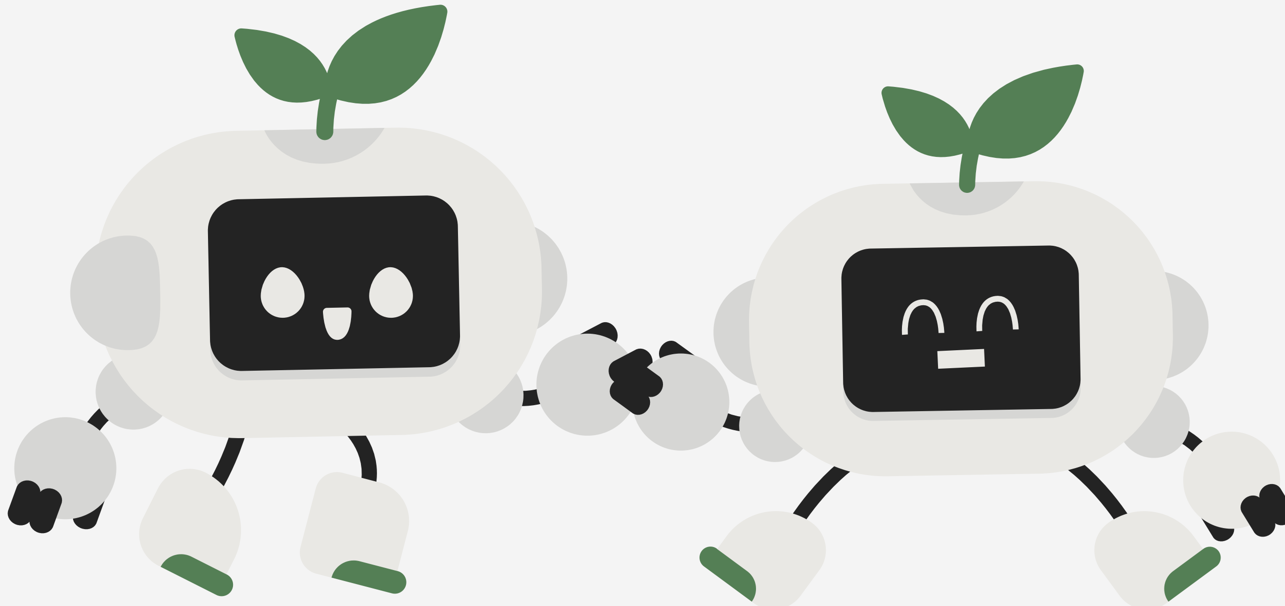
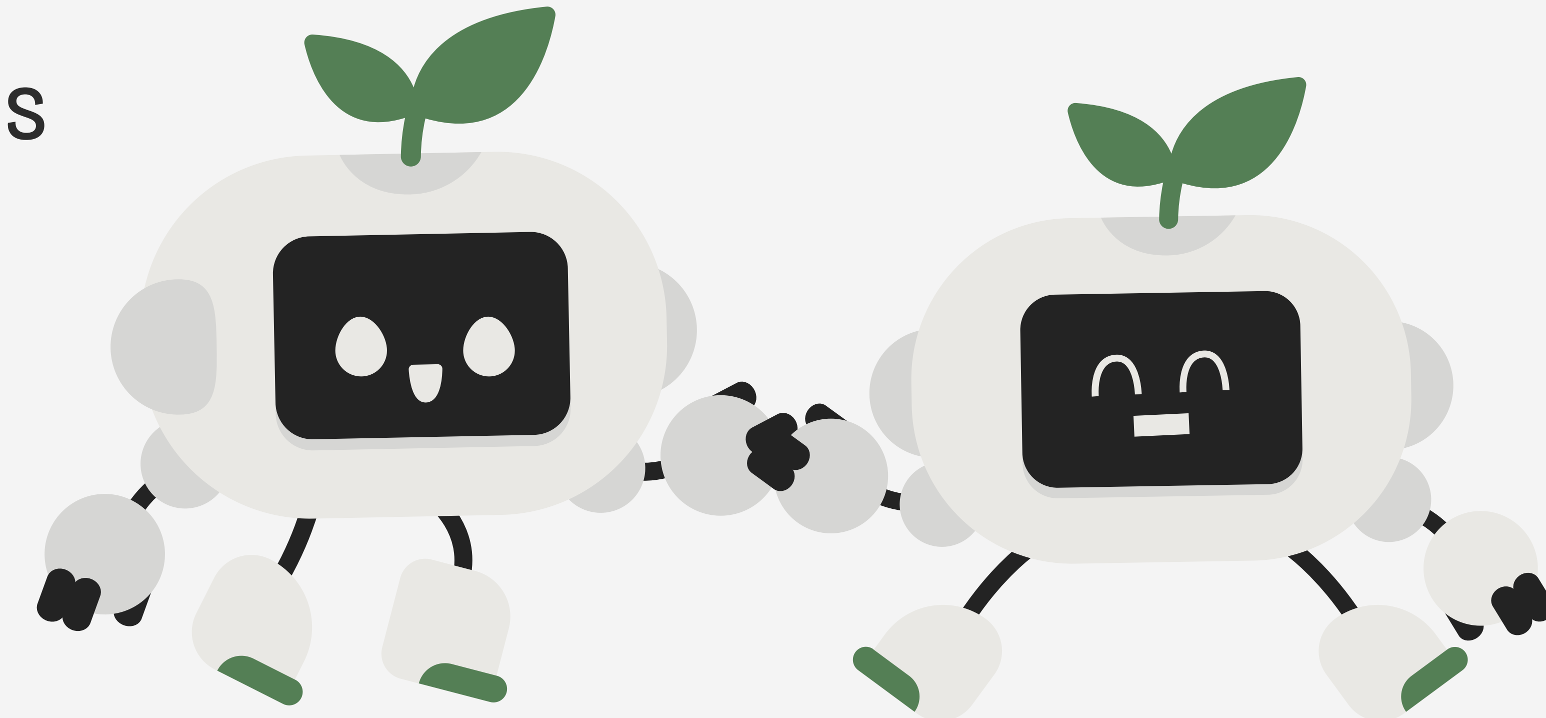


Ideology / Concept

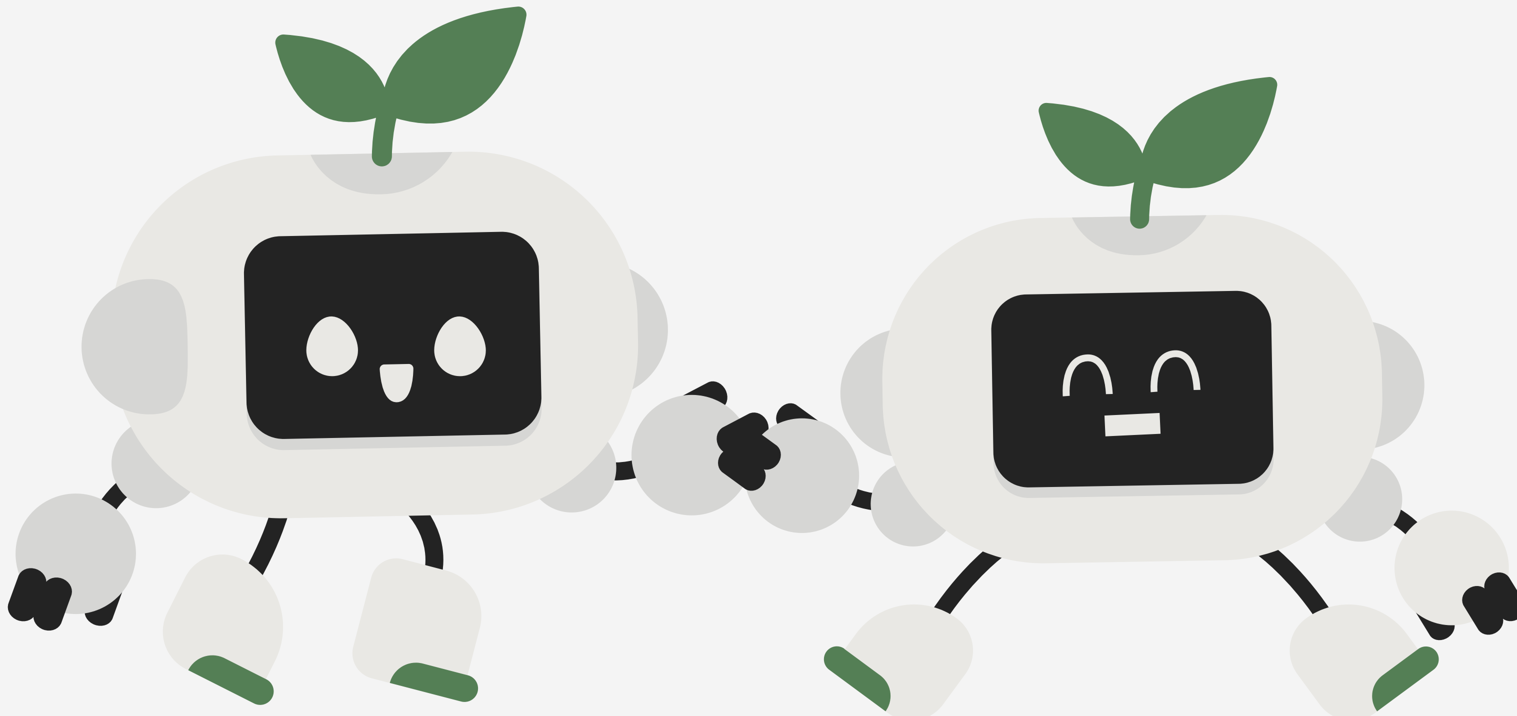
- Simulate evolutionary learning in bipedal robots.
- Robots learn, adapt, and evolve walking strategies over generations.
- Evolutionary algorithms allow self-discovery of optimal movement patterns.
- Phase 1 focuses on laying the foundation for this process.



Phase 1 Goals & Project Structure

Goals:

- Build the bipedal robot prototype (legs, joints, sensors, motors).
- Set up the evolutionary supervisor for multiple robots and generations.
- Define fitness criteria like distance and balance.
- Organize the project structure for modular development.



Phase 1 Goals & Project Structure

Project Structure

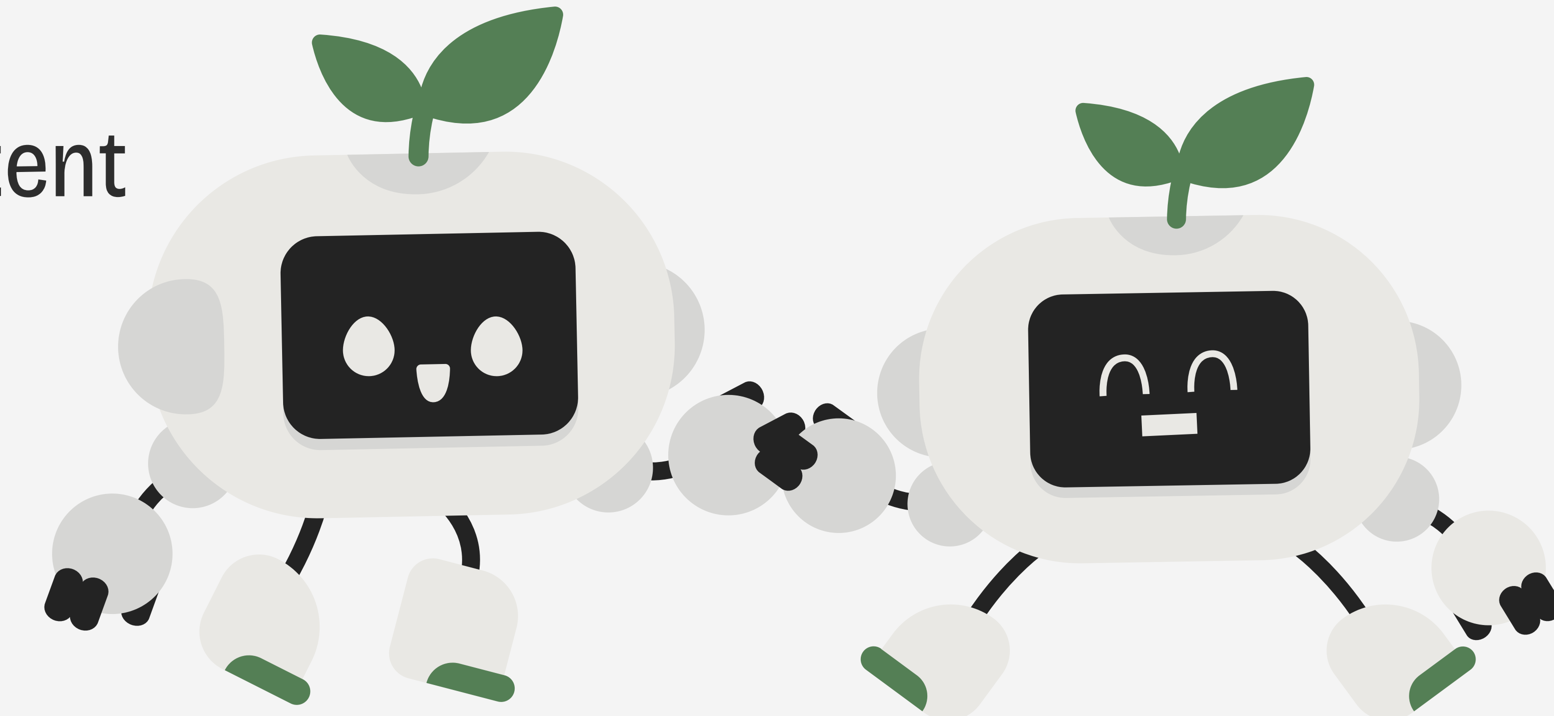
```
bipedal_evolution_project/
├── worlds/
│   └── evolution_world.wbt          # Main Webots world file
├── controllers/
│   ├── evolutionary_supervisor/     # Evolution management
│   │   ├── evolutionary_supervisor.py
│   │   ├── genome.py
│   │   ├── population.py
│   │   └── environment.py
│   └── bipedal_robot/               # Individual robot controller
│       └── bipedal_robot.py
```

Phase 2 - World File

The world is derived from the Humanoid Robot Marathon, which serves as an example environment provided by Webots.

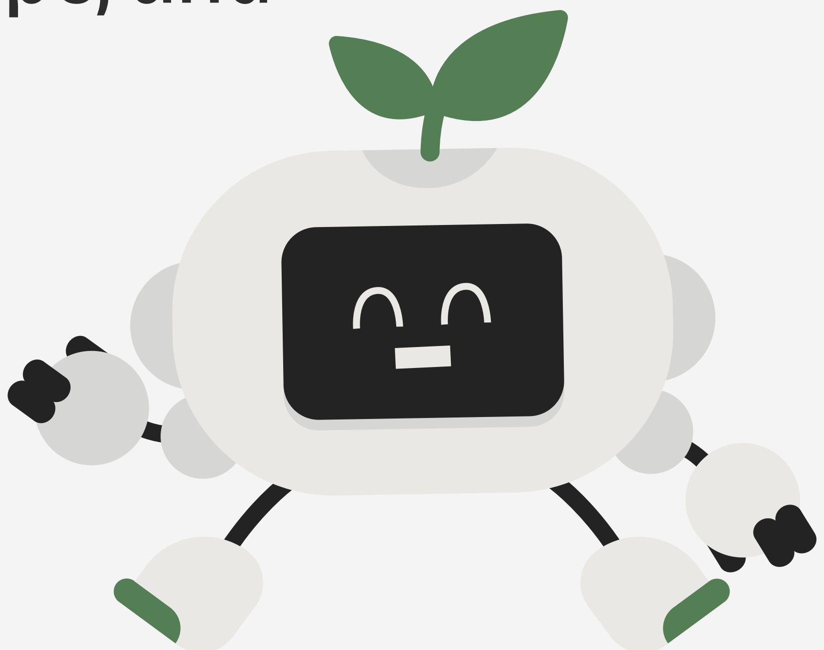
Phase 3- World Re-Design

- Modified and refined the simulation world to better suit project requirements.
- Removed unnecessary elements and simplified the environment.
- Adjusted layout and coordinates for stable robot placement.
- Ensured the redesigned world provides consistent testing conditions.



Phase 3- Robot and Controller Design

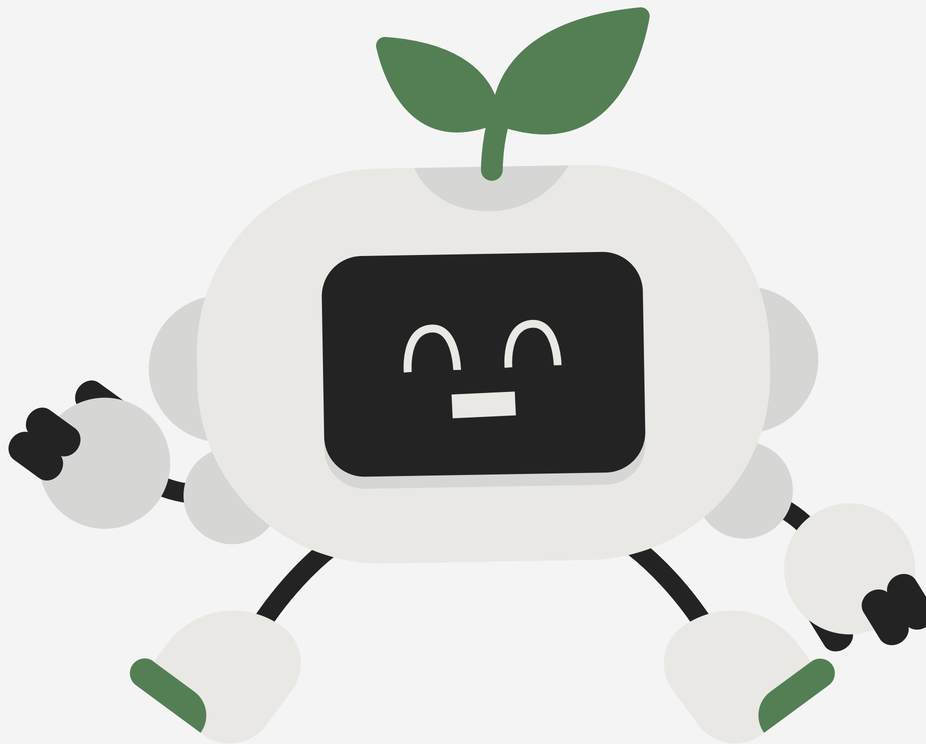
- Began creating the bipedal robot from scratch within Webots.
- Initially attempted placement in the modified world, but encountered coordinate alignment issues.
- Shifted to a simpler rectangular arena for easier debugging and control setup.
- Used fundamental Webots components like HingeJoint, Solid, Shape, and Physics for robot construction.
- Around 70% of the robot structure has been completed.



Phase 3 - Robot Implementation

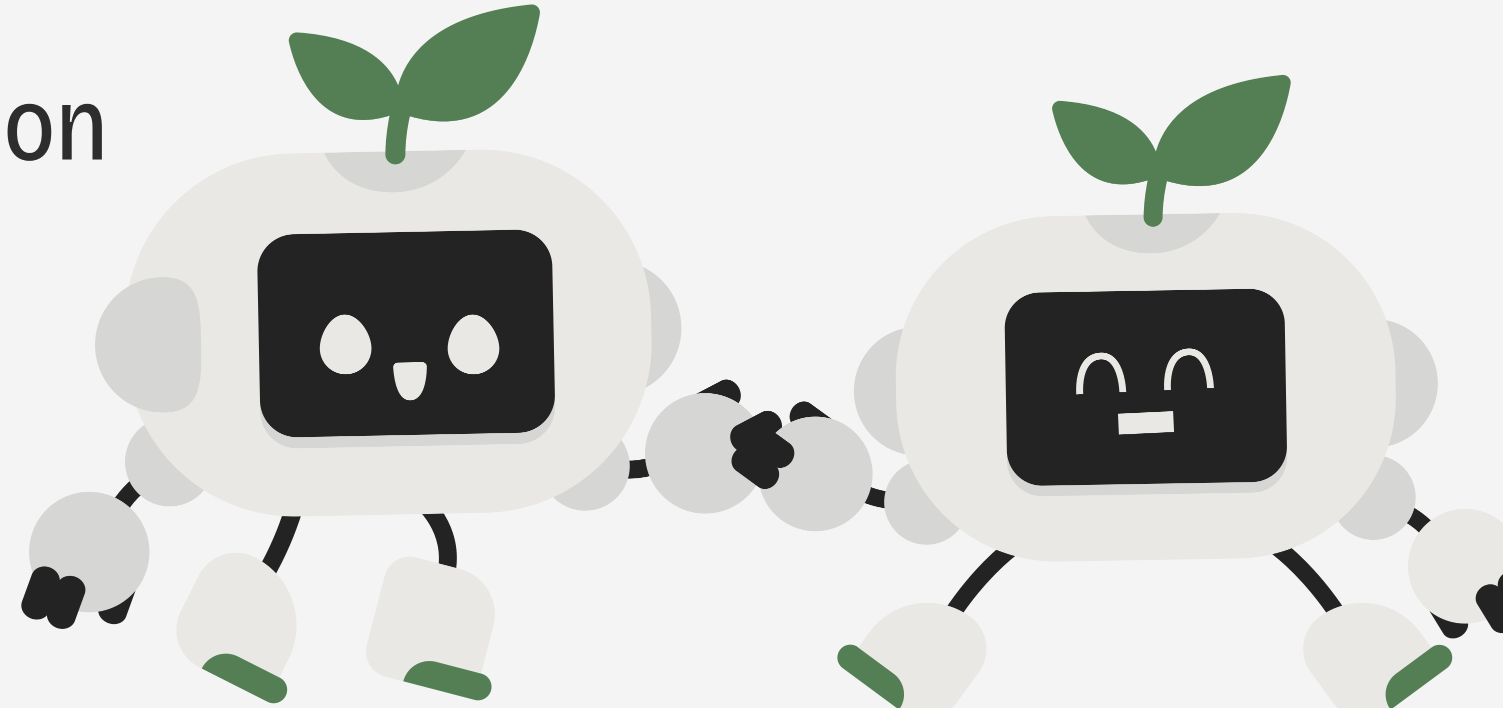
Phase 4 - Challenges in Robot Design

- Hinge joints and leg mechanisms were not functioning correctly.
- Building a robot from scratch was complex and error-prone.
- Few pre-existing bipedal prototypes were available.
- Source code for existing robots was mostly inaccessible.
- Completing a fully functional custom robot was not feasible.



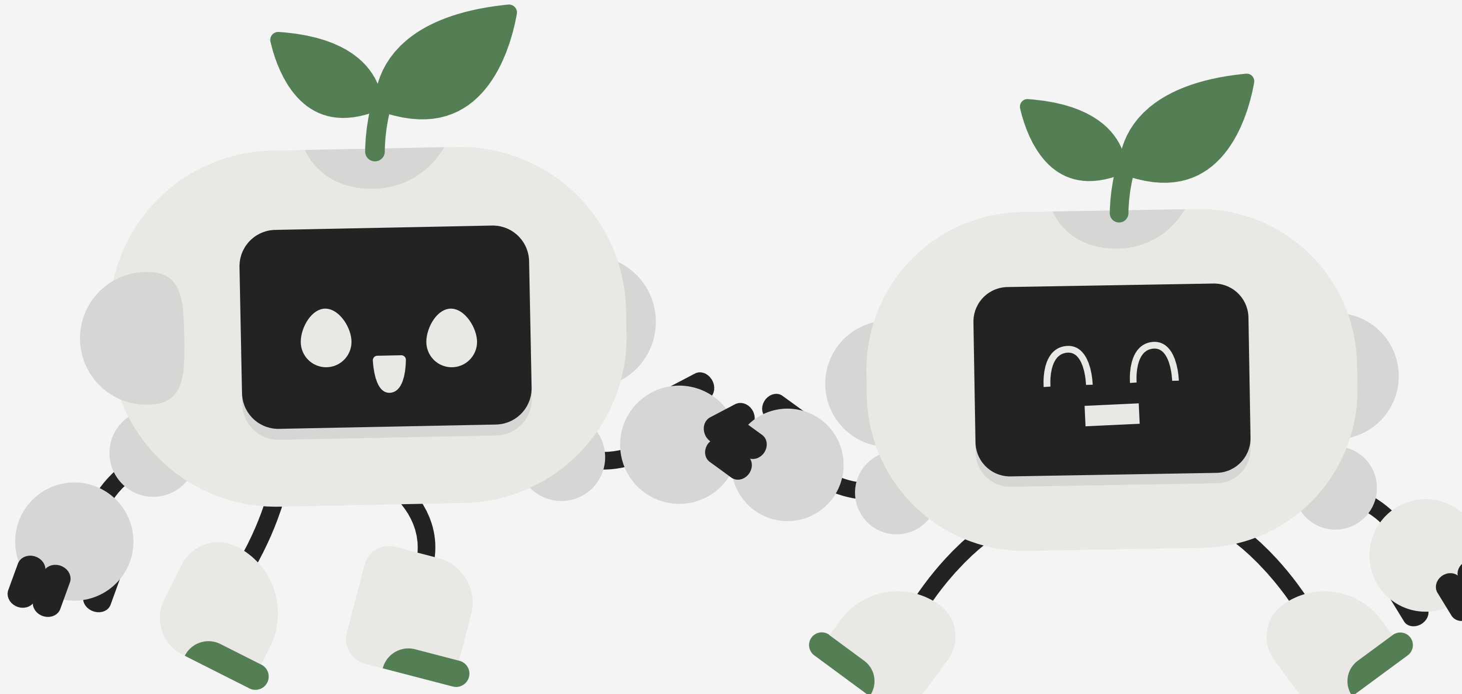
Phase 4 - Solution: Darwin OP3 Robot

- Stable, fully functional robot model available.
- Allows focus on controller programming and evolutionary testing.
- Robot supports walking forward/backward and turning left/right.
- Provides a reliable platform for gait optimization experiments.



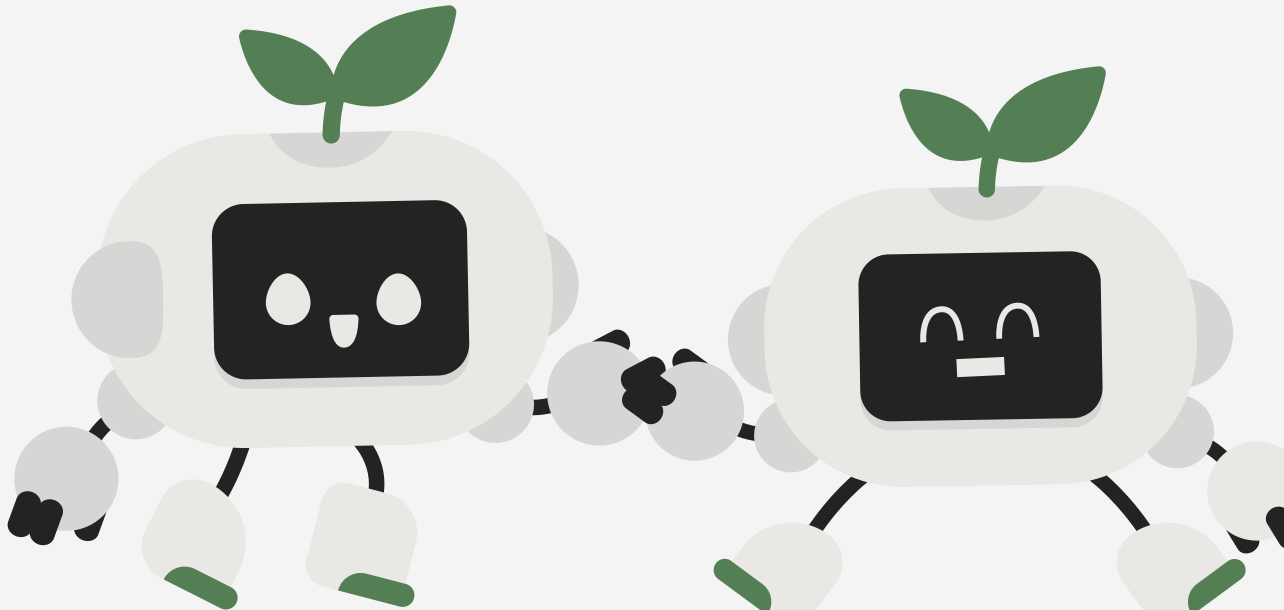
Phase 5 Why Genotype-Based Approach

- Genotype encodes potential walking solutions as motor angles and timings for a stride.
- Allows precise control over gait parameters.
- Provides a clear structure for mutation and crossover during evolution.
- Easier to implement and test in a simulated environment.



Phase 5 - What is Happening

- Pressing ‘E’ triggers the evolutionary process.
- Creates a population of genomes, each representing a walking pattern.
- Evaluates fitness based on distance, balance, and stability.
- Best performers are selected to produce offspring through mutation and crossover.
- Over generations, robot gait gradually improves.



Phase 5 - Results

```
Speed up: 0.4
Speed up: 0.6
Speed up: 0.8
Speed up: 1
Speed up: 1.2
Speed up: 1.4
Speed up: 1.6
Starting evolutionary optimization..
```

```
======= ROBOTIS OP2 AUTO WALK =======
Arrow keys control speed/direction
Space = stop, E = evolutionary optimiza
=====================================
Starting evolutionary optimization...
Evolution Gen 1 best fitness 4000
Evolution Gen 2 best fitness 4000
Evolution Gen 3 best fitness 4000
Evolution Gen 4 best fitness 4000
```

```
Current X=1 A=0 | Fitness=1.008s
Current X=1 A=0 | Fitness=1.008s
Current X=-0.2 A=0 | Fitness=1.008s
Current X=-1 A=0 | Fitness=1.008s
Current X=-1 A=-1 | Fitness=1.008s
Current X=-1 A=-1 | Fitness=1.008s
Current X=-1 A=-1 | Fitness=1.008s
Current X=-1 A=-1 | Fitness=1.008s
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```

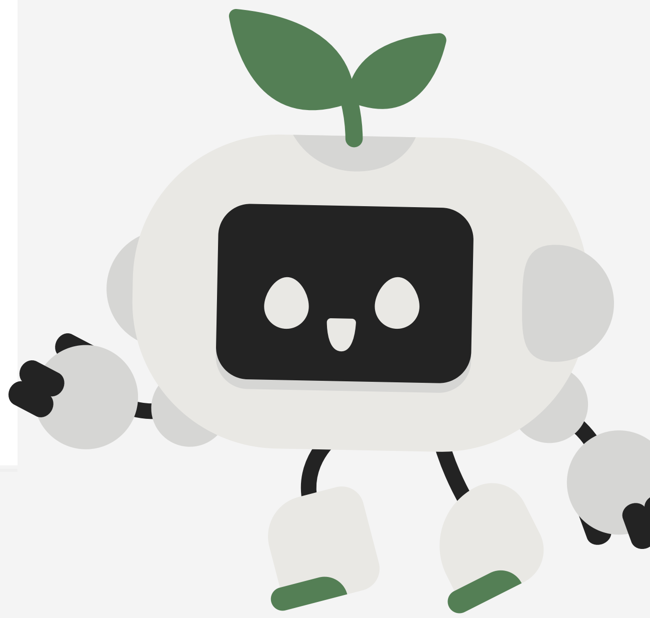

CITATIONS

- World file - https://webots.cloud/run?version=R2023b&url=https%3A%2F%2Fgithub.com%2Fcyberbotics%2Fhumanoid-marathon-competition%2Fblob%2Fmain%2Fworlds%2Fhumanoid_marathon.wbt&type=competition
- https://github.com/cyberbotics/webots/tree/d5658d78a26d5bcddb9f9e983247a675b756ca15/projects/robots/robotis/darwin-op
- Collins, J., Geles, W., Howard, D., & Maire, F. (2018). Towards the Targeted Environment-Specific Evolution of Robot Components. ArXiv. https://doi.org/10.1145/3205455.3205541
- https://youtu.be/5BoxM0SzD7M?si=JBnsus6Dwdl1NB9O
- https://github.com/citbrains/GankenKun_webots.git