Creating and Demonstrating a Dataset for Swarm Mission Generation from Natural Language

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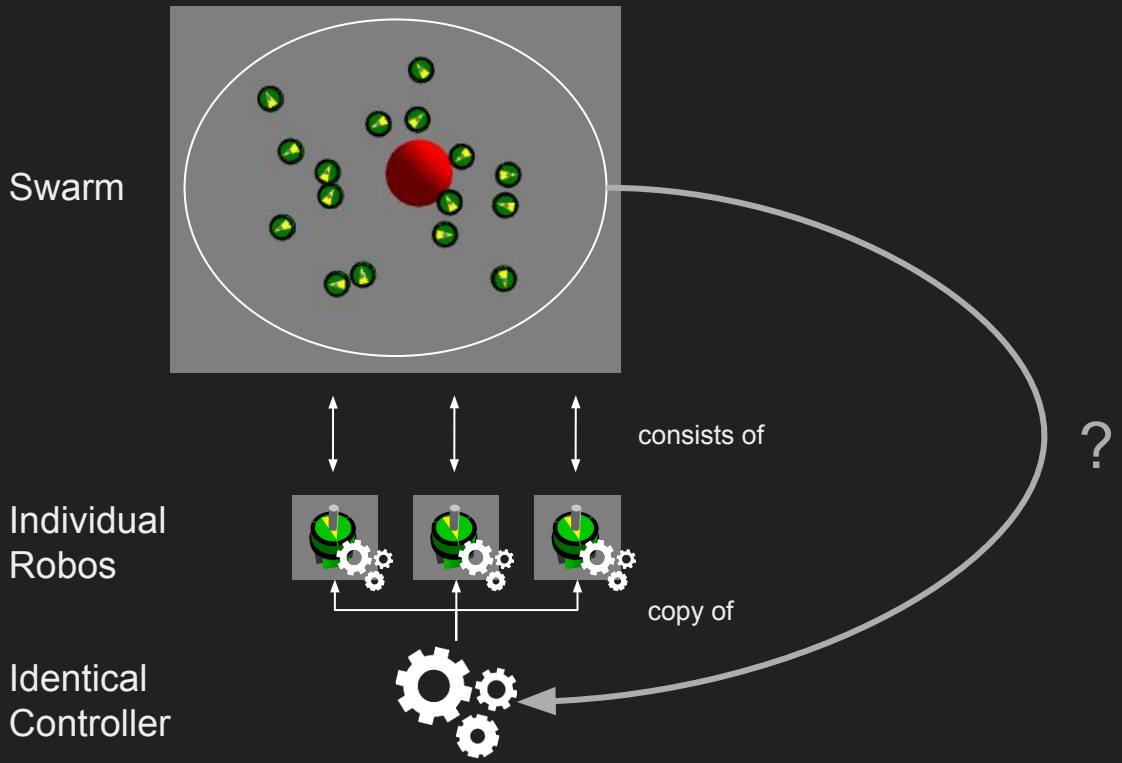
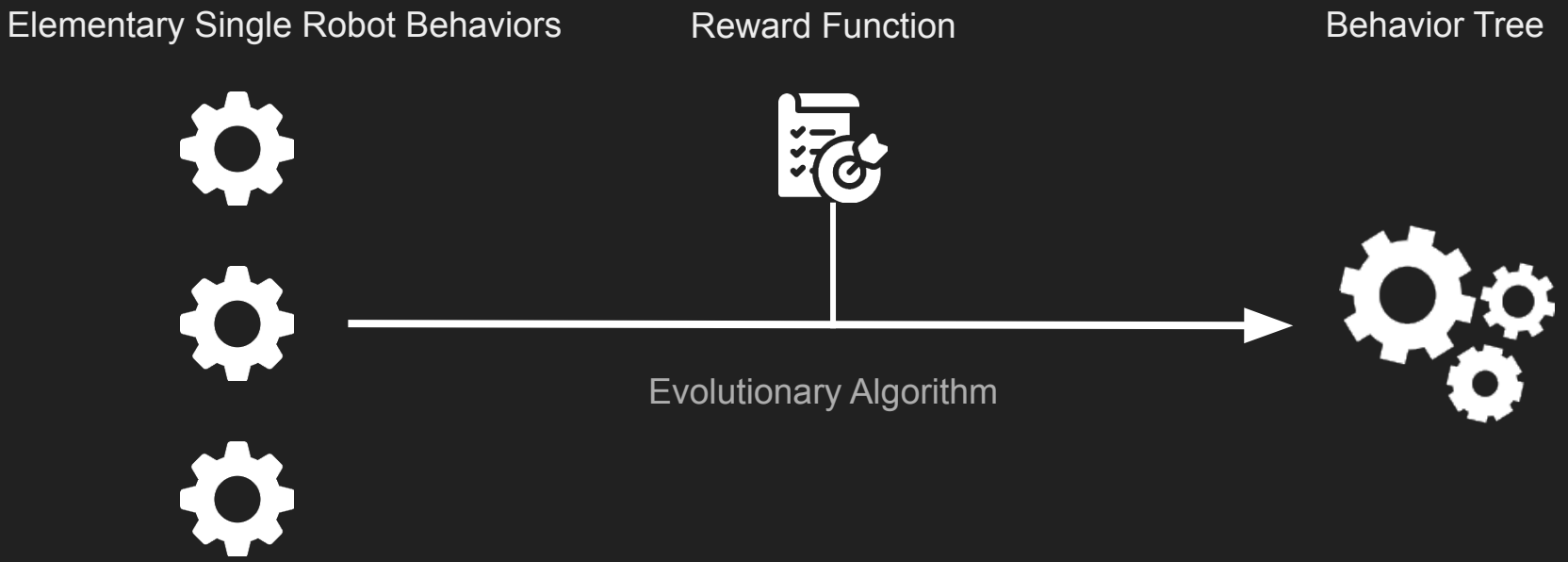
The Micro-Macro Gap

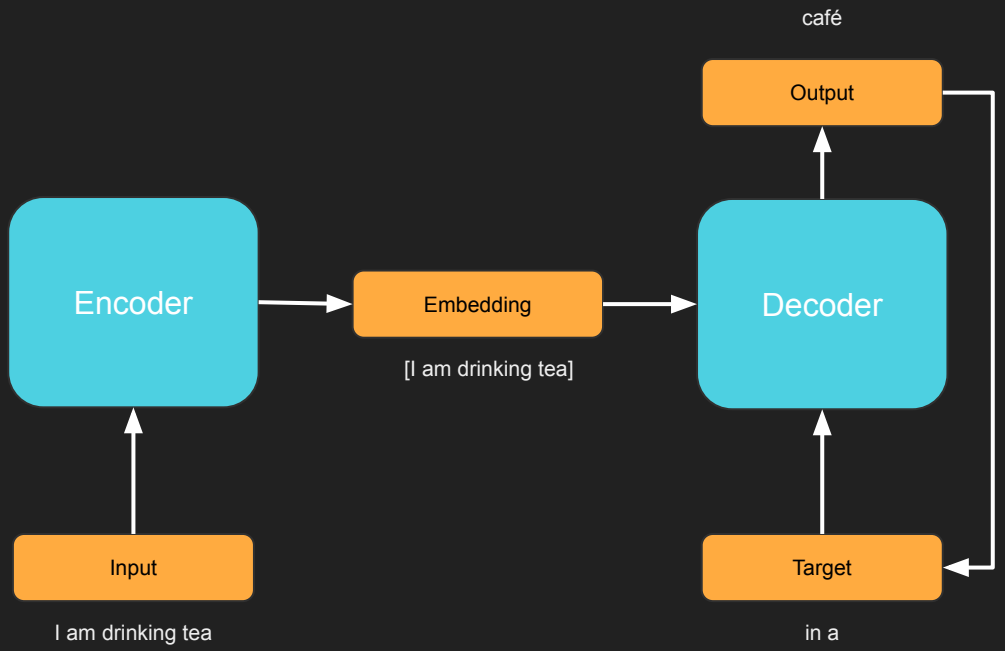


Automatic Modular Design (AutoMoDe-Maple)



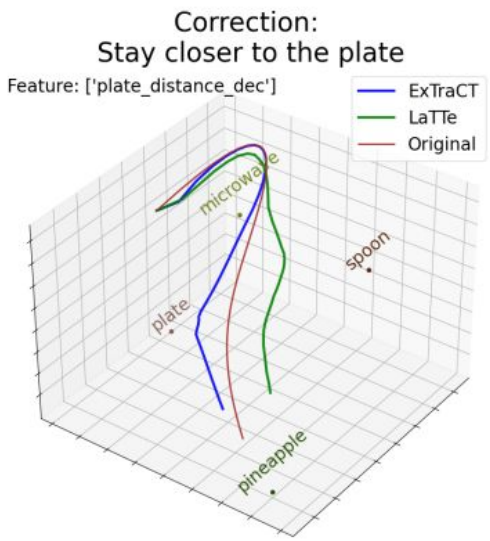
[Kuckling et al. 2018]

Large Language Models: Transformer Architecture

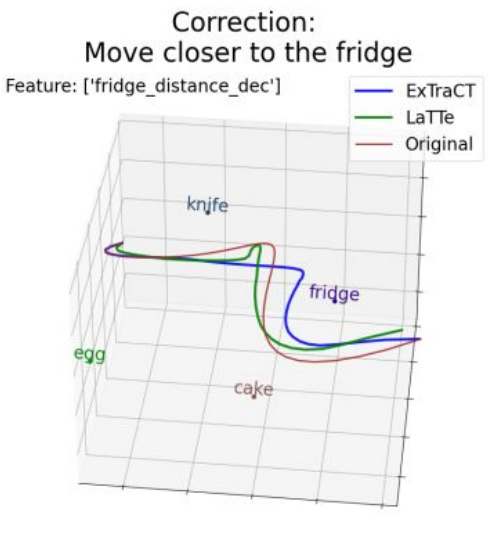


[Vaswani et al. 2017]

LLMs in Robotics: Trajectory Corrections



(a)



(b)

[Bucker et al. 2023]

LLMs in Robotics: BT Generation

A human and LLM-BRAIn created the Behavior Tree to set the robot's following behavior:
"If object is visible, move towards it, take it and process it. Else scan the area."
Which BT do you think the human-written?

```
<BehaviorTree ID="MobileRobotTask">
    <Fallback>
        <Sequence>
            <Condition ID="IsObjectApproached"/>
            <Action ID="TakeObject"/>
            <SubTree ID="ProcessObject"/>
        </Sequence>
        <Sequence>
            <Condition ID="IsObjectVisible"/>
            <Sequence>
                <Action ID="MoveToObject"/>
                <Action ID="TakeObject"/>
            </Sequence>
        </Sequence>
        <Action ID="ScanAreaForObject"/>
    </Fallback>
</BehaviorTree>
```

```
<BehaviorTree ID="FindAndTakeObject">
    <Fallback>
      <Sequence>
        <Condition ID="IsObjectApproached"/>
        <Action ID="TakeObject"/>
        <SubTree ID="ProcessObject"/>
      </Sequence>
      <Sequence>
        <Condition ID="IsObjectVisible"/>
        <Action ID="MoveToObject"/>
      </Sequence>
      <Action ID="ScanAreaForObject"/>
    </Fallback>
</BehaviorTree>
```

[Lykov et al. 2023]

Can LLMs **directly** generate controllers for robot swarms?

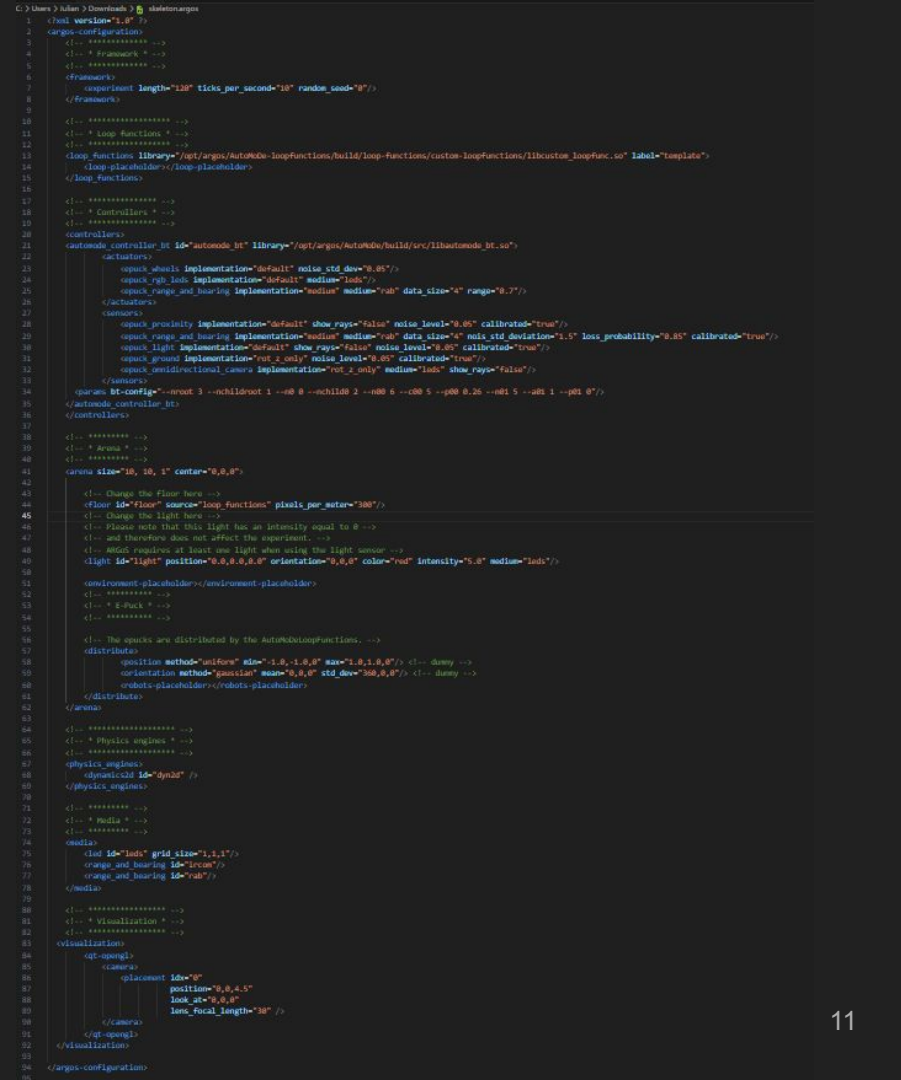
Contribution

1. Dataset of **Mission Descriptions** with respective **Mission Configuration** for AutoMoDe.

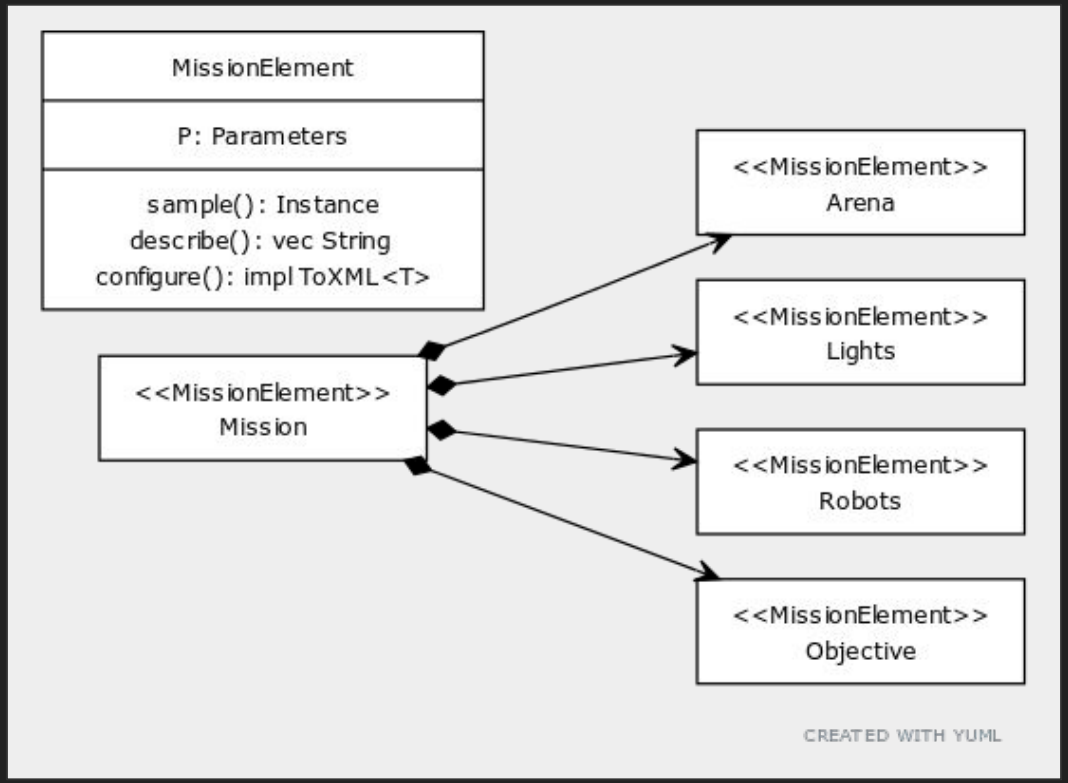
2. Demonstrate application by **finetuning an LLM** to the Dataset.

Swarm Mission Model

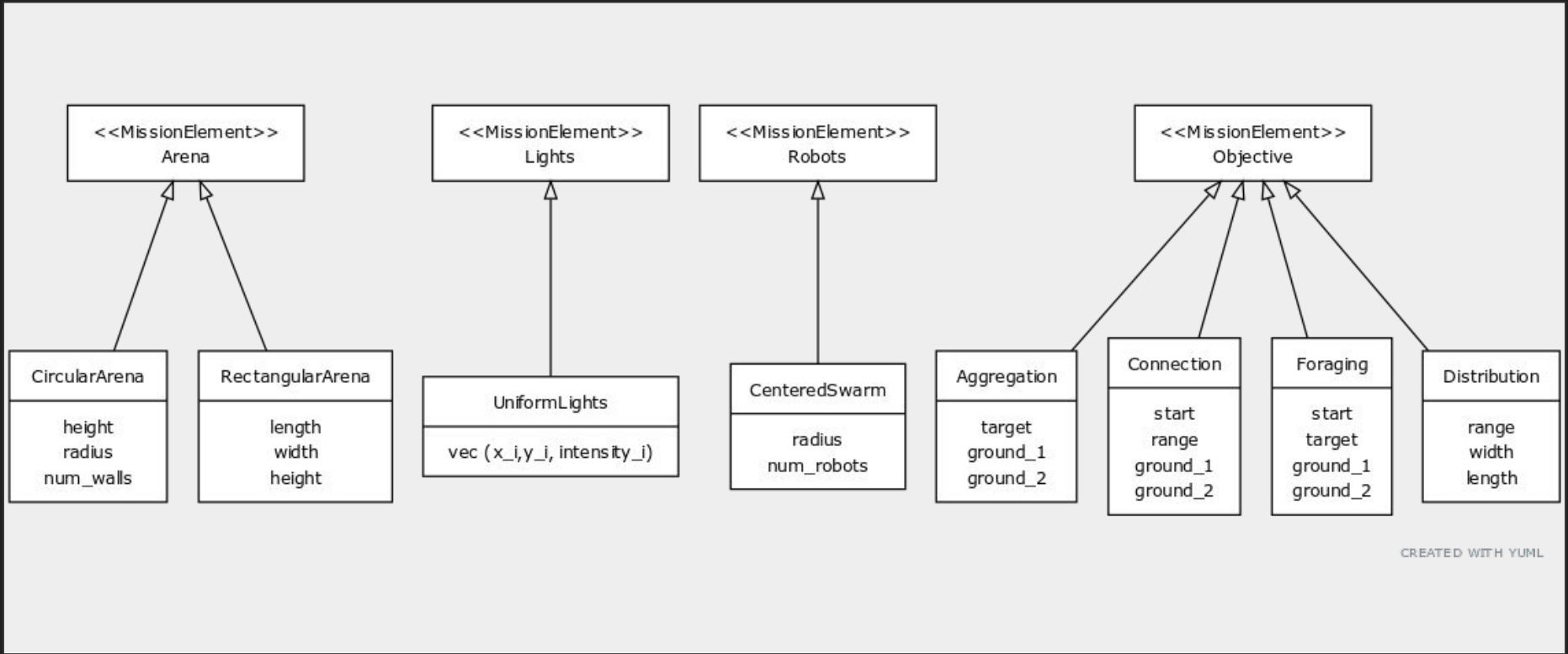
- Arena
- Lights
- Robot Swarm
- Objective



Mission Elements



Mission Element Implementations

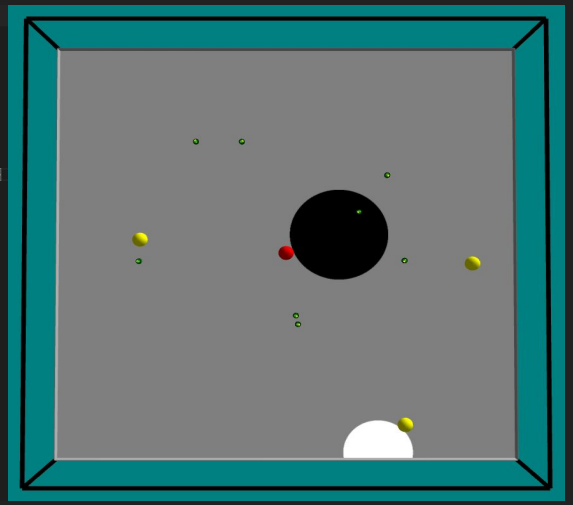


Example Mission

argos_config

tmp > argos_config

```
<?xml version="1.00" ?>
<config>
  <swarm-elems>
    <entity quantity="8" max_trials="100">
      <e-puck id="epuck">
        <controller config="automode_bt"/>
      </e-puck>
    </entity>
  </swarm-elems>
  <env-elems>
    <light id="light_0" position="-2.43,b-1.54,0.00" orientation="360,0,0" color="yellow" intensity="3.58" medium="leds"/>
    <light id="light_1" position="0.19,1.90,0.00" orientation="360,0,0" color="yellow" intensity="6.43" medium="leds"/>
    <light id="light_2" position="-0.15,-2.42,0.00" orientation="360,0,0" color="yellow" intensity="4.48" medium="leds"/>
    <box id="wall_0" size="0.01,5.80,0.10" movable="false">
      <body position="0,-2.96,0.00" orientation="90.00,0.00,0.00"/>
    </box>
    <box id="wall_1" size="0.01,5.91,0.10" movable="false">
      <body position="2.90,0,0.00" orientation="0.00,0.00,0.00"/>
    </box>
    <box id="wall_2" size="0.01,5.80,0.10" movable="false">
      <body position="0,2.96,0" orientation="90.00,0.00,0.00"/>
    </box>
    <box id="wall_3" size="0.01,5.91,0.10" movable="false">
      <body position="-2.90,0,0" orientation="0,0.00,0.00"/>
    </box>
    <arena-attrib size="5.80,5.91,2.24"/>
  </env-elems>
  <objective-elems>
    <spawnCircle position="0,0,0" radius="2.06"/>
    <circle position="-2.82,-1.19" radius="0.45" color="white"/>
    <circle position="0.26,-0.69" radius="0.64" color="black"/>
    <objective type="connection">
      <objective-params conn_start="black" conn_end="white" connection_range="0.49"/>
    </objective>
  </objective-elems>
</config>
```

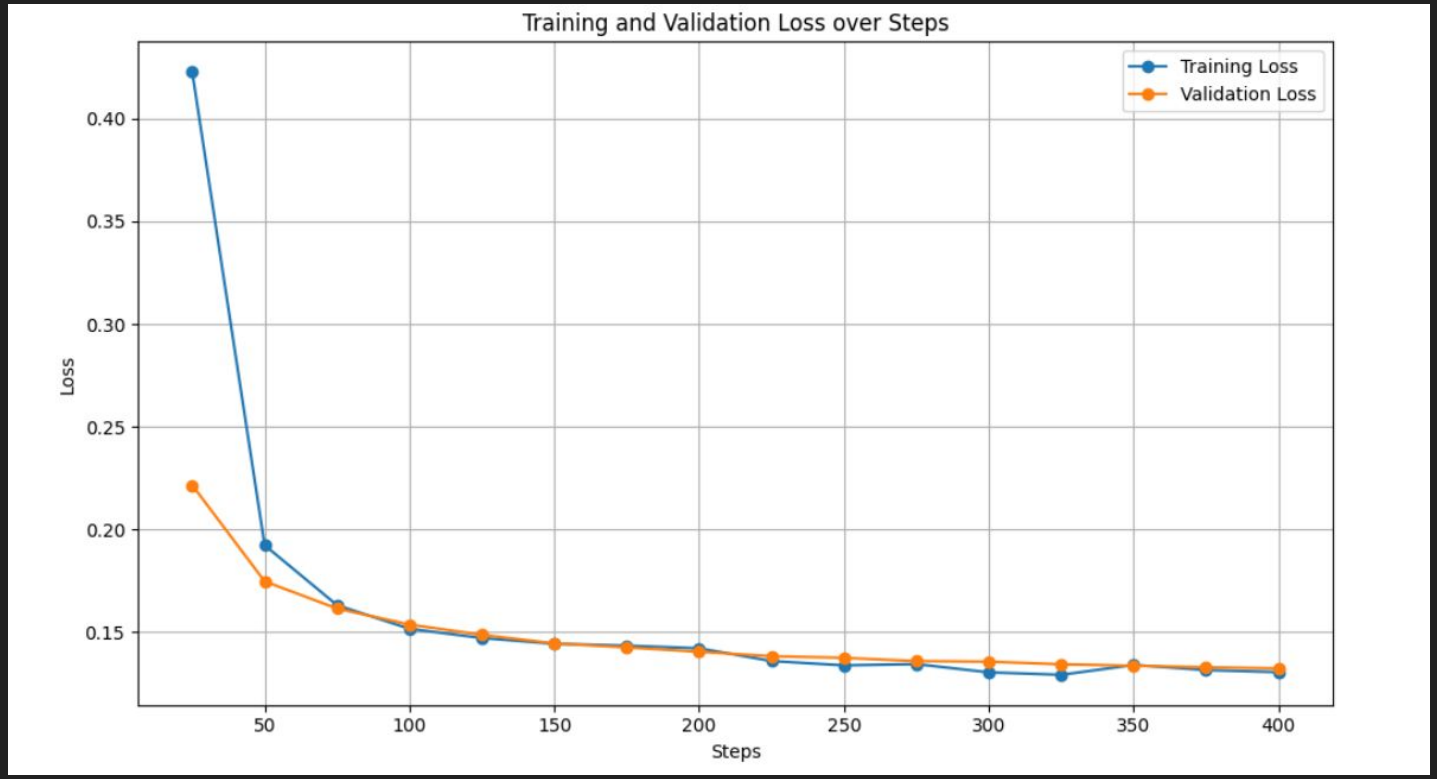


“The rectangular area has dimensions 5.91 m x 5.80 m x 2.24 m. In the arena, 3 lights are evenly spread out with intensities 3.58, 6.43, 4.48. Within a 2.06-meter radius around the center, 8 robots are evenly positioned. Picture two circles—one at [-2.82, -1.19] with a radius of 0.45 meters, colored in white, and another at [0.26, -0.69] with a radius of 0.64 meters in black. The objective for the robots is to form a connection from the black to the white circle while maintaining a distance of just under 0.49 m.”

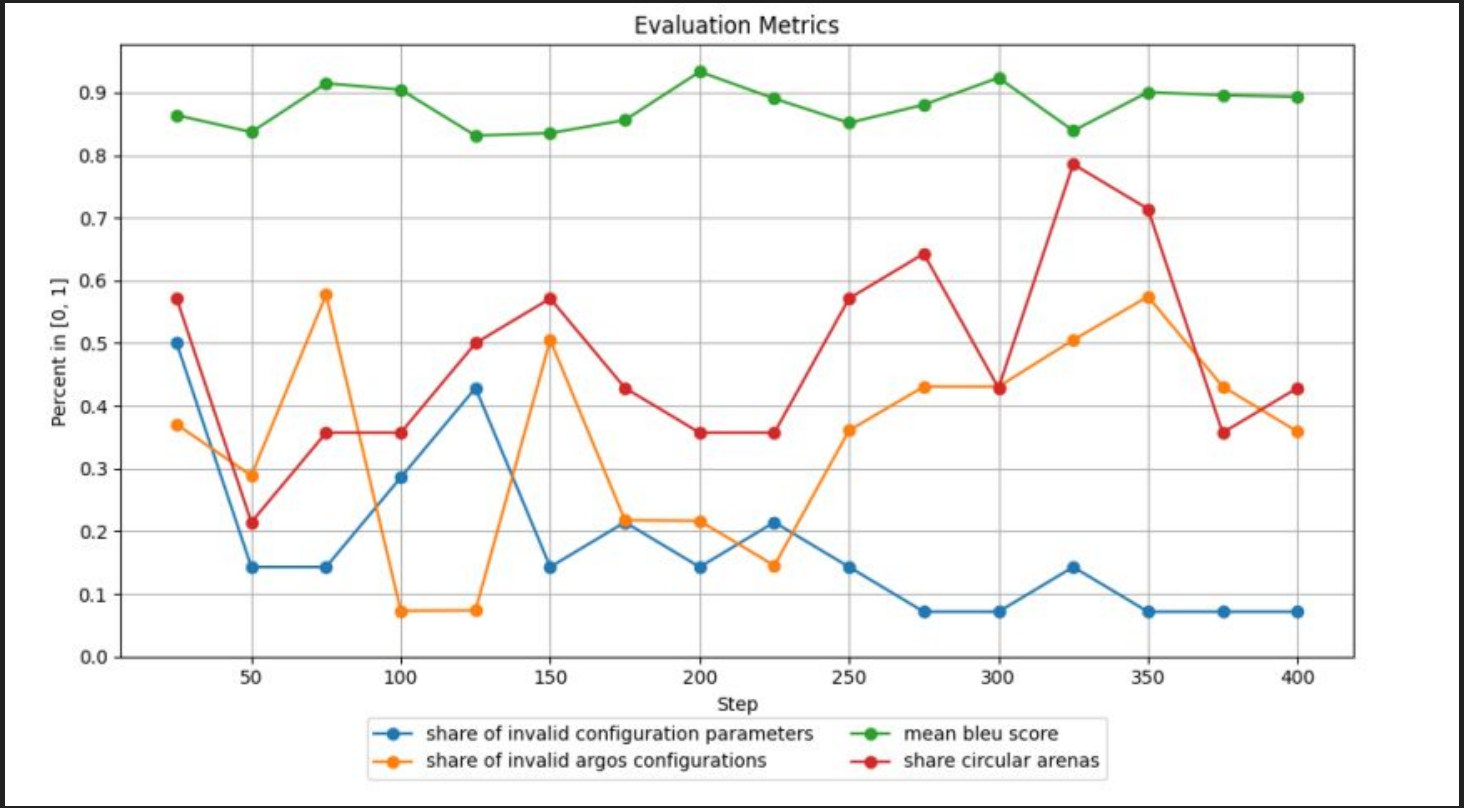
LLM Finetuning - Technology

400 Training Steps, 7.5h training

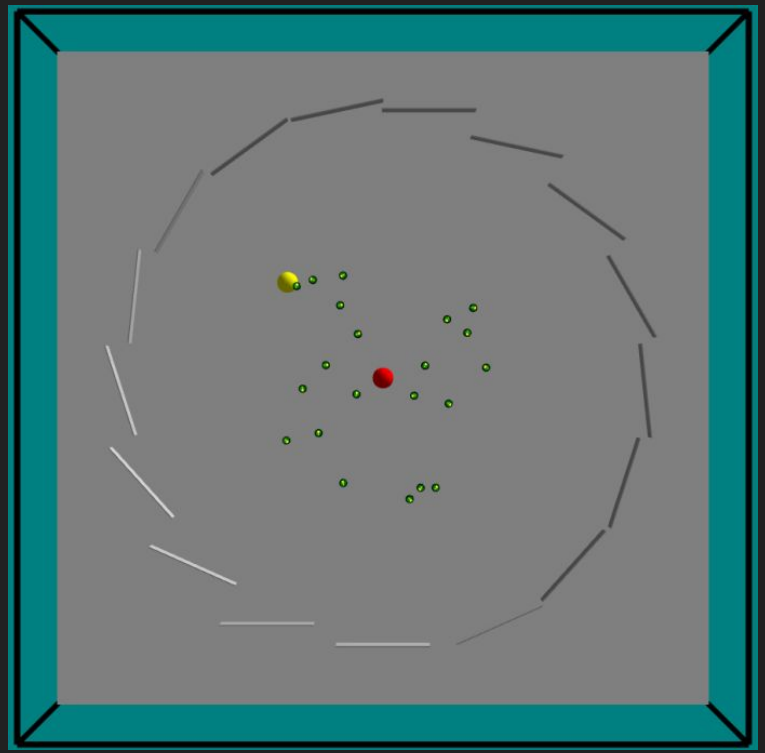
LLM Finetuning - Training Loss



Mission Generation Results - Evaluation



Invalid Circular Walls



Representative example of invalid wall placement

General Results

- Extensible framework for generating a dataset of swarm mission descriptions with corresponding configurations
- Basis for finetuning an LLM model to approach micro-macro gap
- Demonstrate working model that declaratively allows to configure using natural language
- Clear indications for why result crashes when it does
- Model fills in missing required data

“The swarm’s goal is to cover an area of 0.55 by 1.29 meters while ensuring connectivity”

```
<objective type="distribution">
  <objective-params area="0.55,1.29" connection_range="0.25"/>
</objective>
```

filled in by model

https://github.com/julianjandeleit/swarm_descriptions