

### ! The Challenge

Testing DRL agent requires thousands of expensive simulations

40s - 5min per simulation 🚗⌚

1000 tests = 16+ hours!

### Current Solution: Indago Framework

DRL Agent → Surrogate Model → Env Generator

✗ MLPs lose spatial information

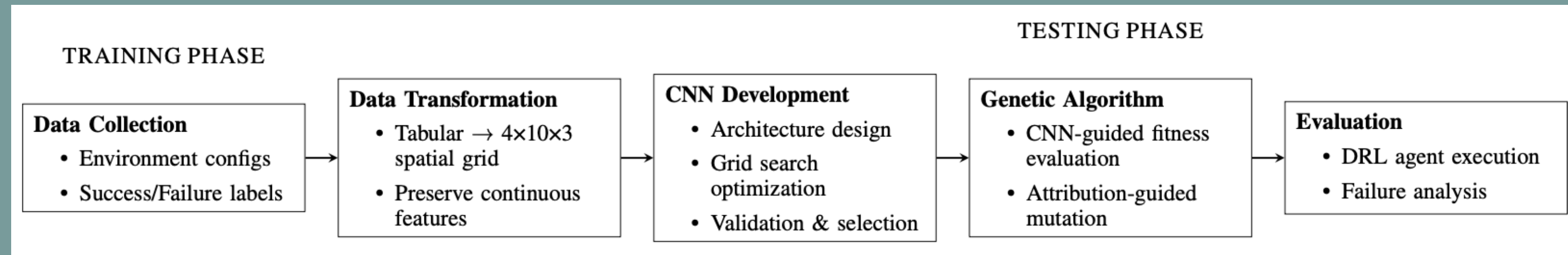
### 💡 Our Hypothesis

CNNs should **OUTPERFORM** MLPs for spatial problems!

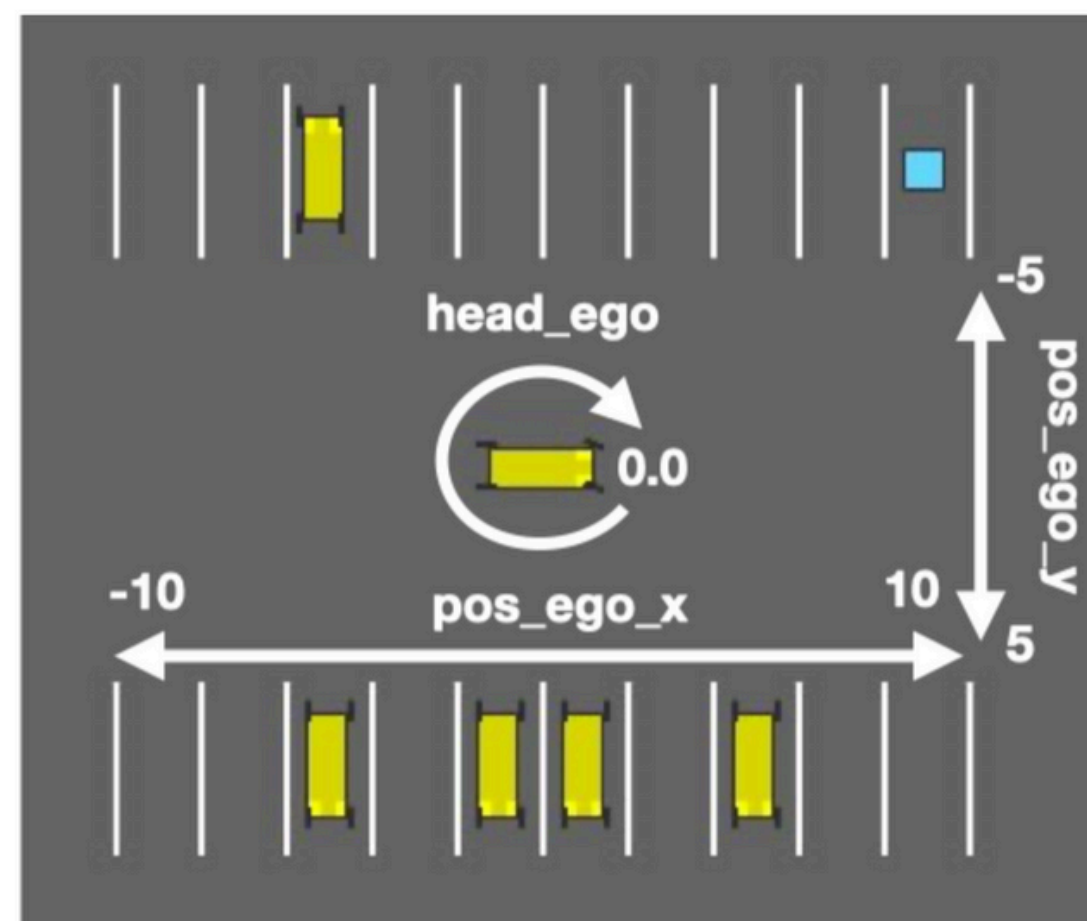
- ✅ Translation Invariance
- ✅ Spatial Patterns
- ✅ Parameter Efficiency

RQ1: What architectural and design choices lead to effective CNN-based surrogate models for DRL testing?  
RQ2: How does the performance of the CNN-based surrogate model compare to an MLP-based surrogate baseline?

### Methodology



### Environment



```

{
  "env_configuration": {
    "num_lanes": 10,
    "goal_lane_idx": 20,
    "head_ego": 0.0,
    "pvehicles": {
      3, 5, 6, 8, 13
    },
    "pos_ego": (0.0, 0.0)
  }
}
  
```

(a)

An configuration of the Parking environment in the High-wayEnv simulator [2]. The bottom part (B) shows the configuration of the environment in JSON. On the top (A) is a rendered of that environment [1]

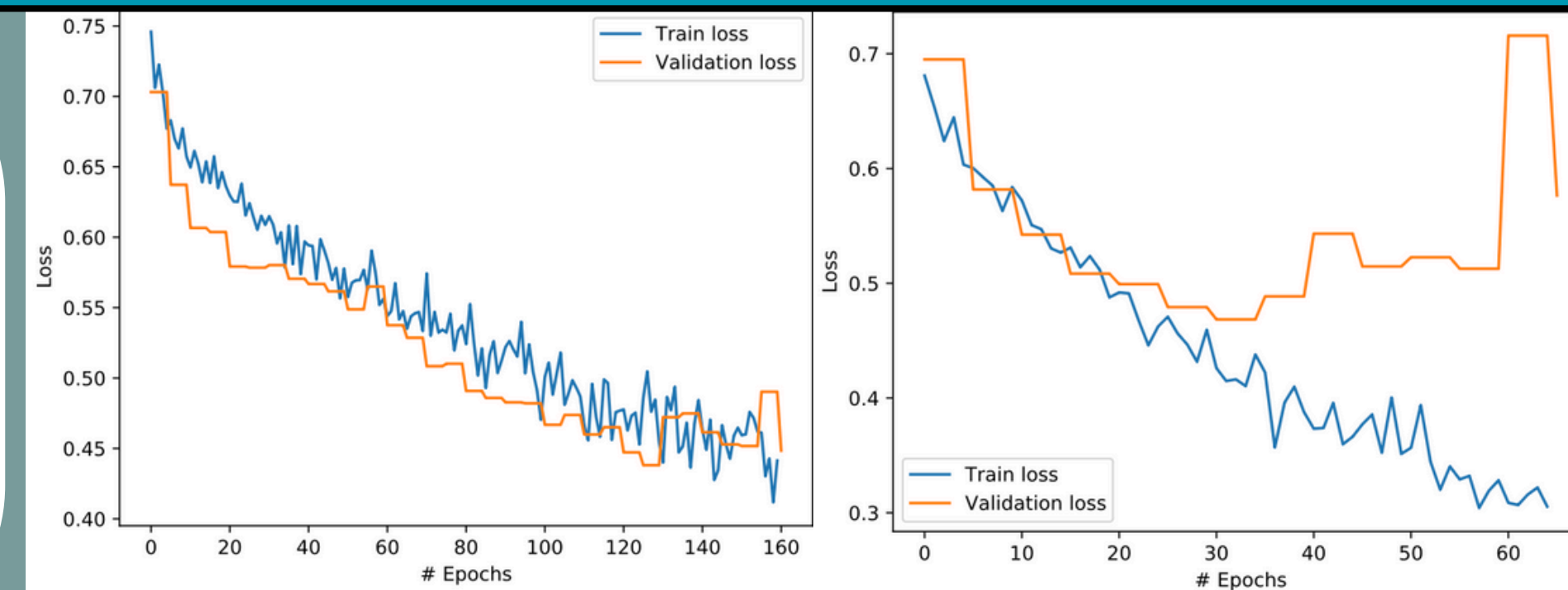
(b)

### Results and findings

Left Graph (Good Model): Small gap between train/validation loss = good generalization → Best performance (0.62 failure rate)

Right Graph (Poor Model): Large gap = overfitting → Worse performance (0.43 failure rate)

Models with better generalization outperform those with high validation metrics



CNN achieves 72% improvement in failure discovery  
Significantly higher diversity across all metrics  
All differences statistically significant ( $p < 0.001$ )

Metric	Sub-Metric	MLP (Baseline)	CNN (Ours)
Failure Rate	Mean Failures Discovered	14.98	25.76
Input Diversity	Coverage (%)	59.0%	70.0%
	Entropy (%)	6.8%	19.6%
Output Diversity	Coverage (%)	47.6%	68.7%
	Entropy (%)	58.2%	69.4%

[1] Matteo Biagiola and Paolo Tonella. Testing of deep reinforcement learning agents with surrogate models. ACM Transactions on Software Engineering and Methodology, 2024.

[2] Edouard Leurent. An environment for autonomous driving decision-making. <https://github.com/eleurent/highway-env>, 2018.