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RoboCup Brasil
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Dribble in the Mind: Exploring Causality with Cognitive Soccer Agents

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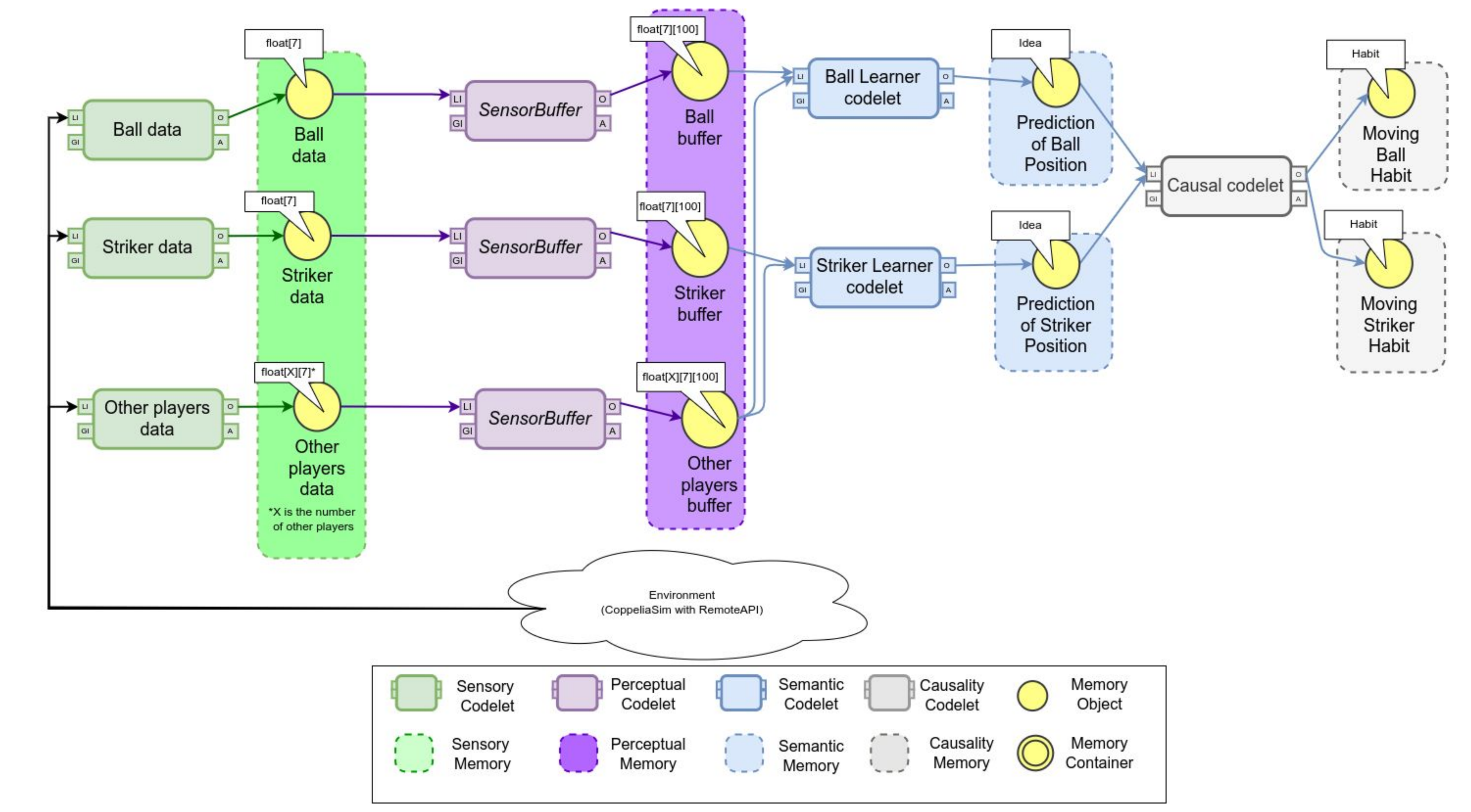
Why Causality Matters in Robotics

Can robots read intentions from motion, like Pelé did in 1970?
This study investigates whether an artificial goalkeeper can infer hidden causes from limited sensor input — through abductive reasoning and cognitive modeling.

Cognitive Architecture

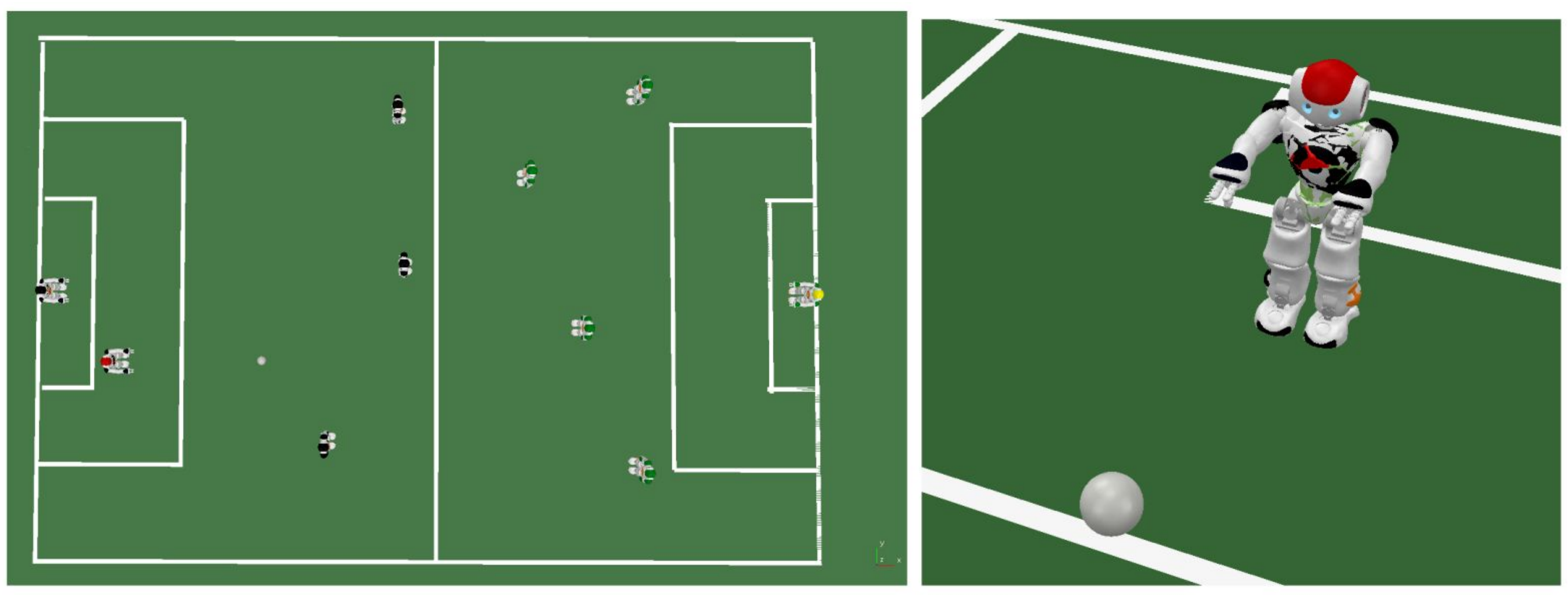
A modular system built with CST, consisting of Sensory Modules (real-time simulation data), Perceptual Memory (buffered history), Semantic Predictors (classifiers), and Causal Reasoning (abductive logic + learned habits).



Cognitive modules: Sensory (green), Perceptual (purple), Semantic (blue) and Causal (white).

Simulation Setup

The experiments took place in a **RoboCup Standard Platform League (SPL)** environment simulated using **CoppeliaSim**. Two **NAO robots** were active: a striker and a goalkeeper. The **striker** was programmed to approach the ball and kick it with a randomized force vector. The **goalkeeper**, restricted to partial and indirect sensory input, attempted to predict the trajectories of both the ball and the striker in real time, relying only on perceptual memory and causal inference. Passive, **static players** were randomly positioned in each scenario, serving as visual and spatial obstacles to increase environmental complexity. This setup simulates the uncertainty and occlusion typical in real-world robotics scenarios.



Experiments

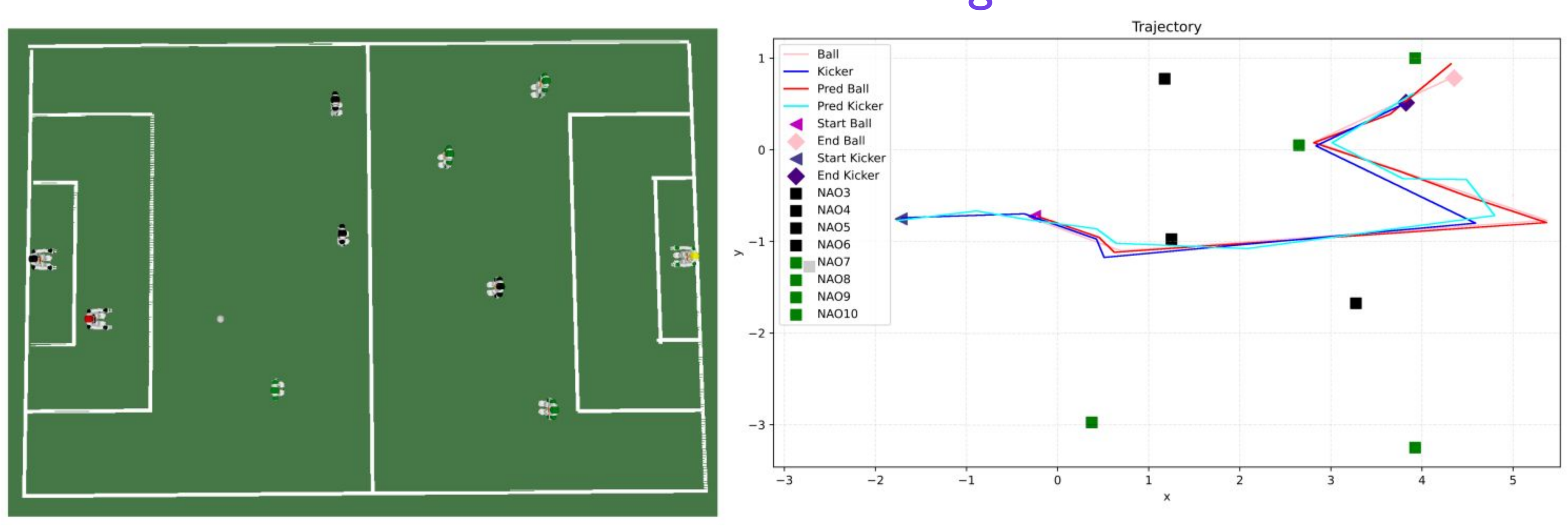
The cognitive architecture was trained **over 100 million simulation steps**, learning to predict future positions of both the ball and the striker from observed trajectories and environmental context. To assess generalization, the model was tested on previously **unseen variations**: increased field friction, heavier and larger balls, and different numbers of players on the field.

Results and Insights

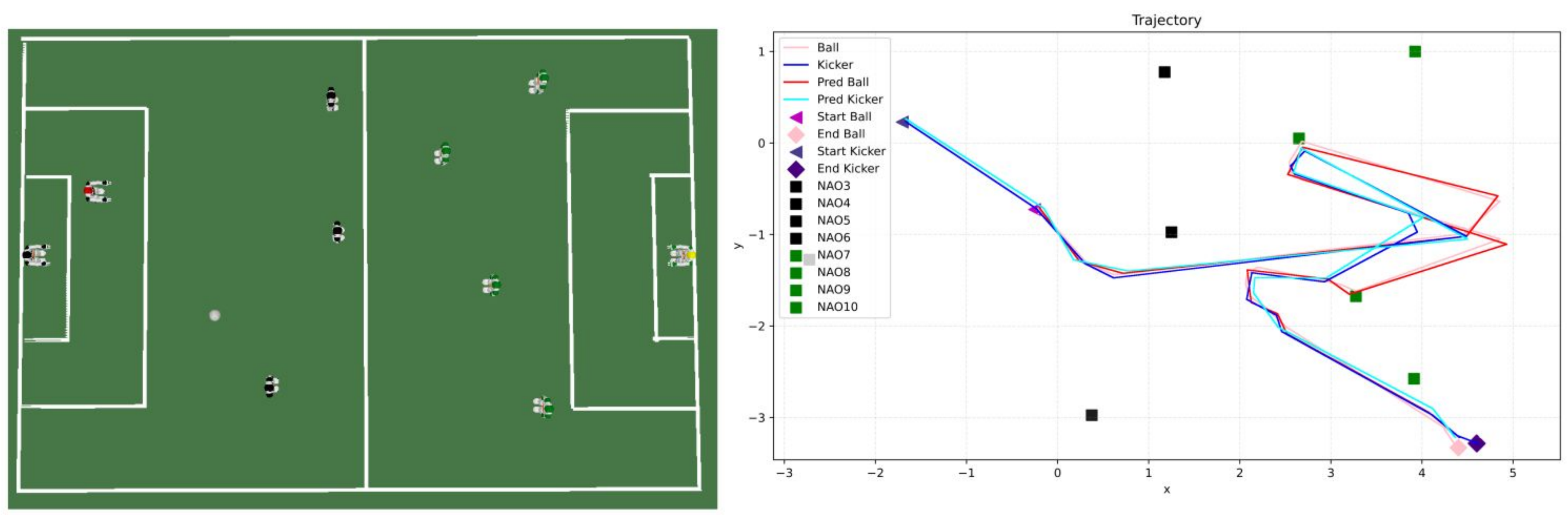
The results show that the goalkeeper agent effectively internalized the environment's dynamics, maintaining accurate predictions of both the striker and the ball in most scenarios. Striker movement predictions remained consistent across conditions, while ball predictions exhibited slight deviations — especially under increased friction, which affected deceleration. Despite these variations, the model generalized well, even when faced with heavier balls and greater spatial interference. This indicates that abductive reasoning, implemented through CST, allows the agent to adapt its inferences beyond simple pattern recognition.

Metric / Phase	Training	Test 1: Friction	Test 2: Ball	Test 3: Players
Ball Error	2.84	3.06	2.92	3.01
Striker Error	2.93	3.11	2.89	3.02
Average Euclidean Error	2.89	3.09	2.91	3.02
Ball Error (Std. Dev.)	≈ 0.15	≈ 0.17	≈ 0.14	≈ 0.16
Striker Error (Std. Dev.)	≈ 0.13	≈ 0.16	≈ 0.13	≈ 0.15

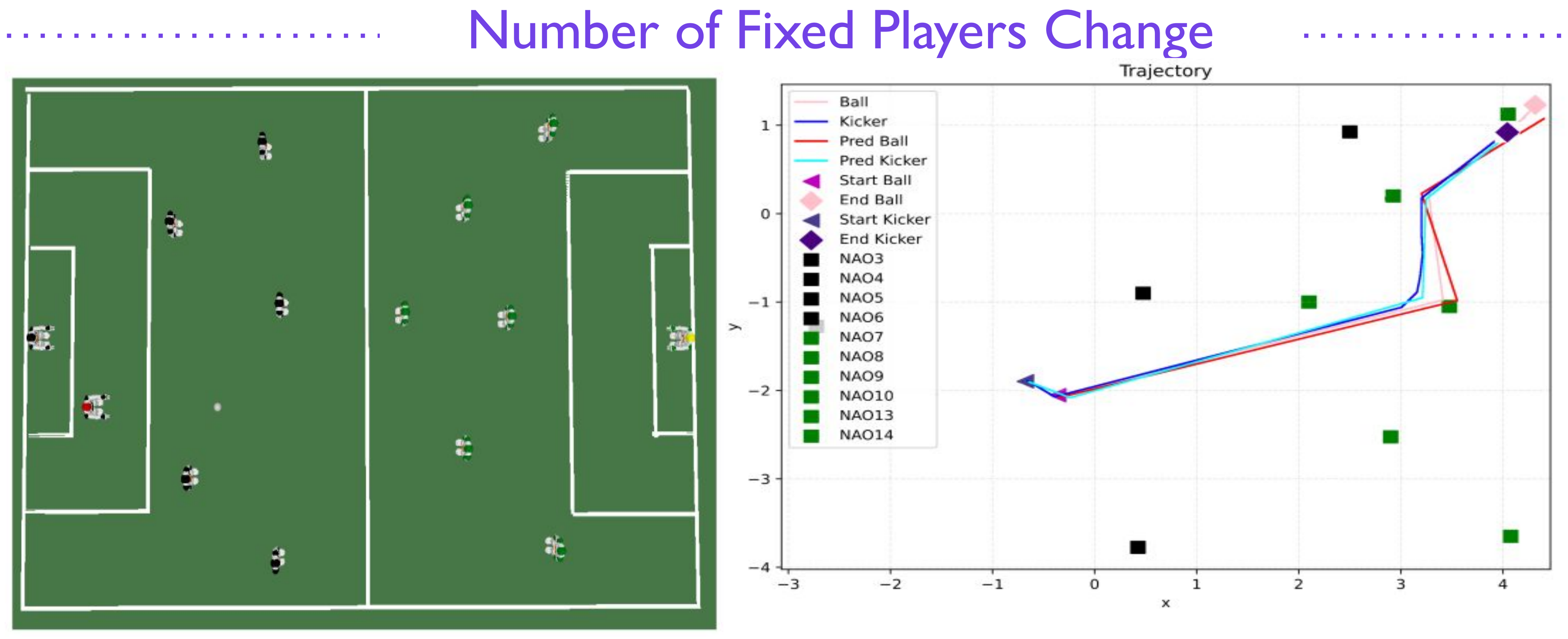
Friction Change



Ball Change



Number of Fixed Players Change



Conclusion

The architecture supports causal inference from partial data by integrating abductive logic with CST. The agent generalizes effectively across scenarios with varying friction, ball properties, and player density. It demonstrates robust trajectory prediction, combining statistical learning with symbolic reasoning for adaptable and context-aware performance.

Repository: https://github.com/leolellisr/causality

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