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Deep Reinforcement Learning for Optimizing Penalty Kick Strategies in Football: A Comparative Study of PPO and IPPO

2026 IEEE 5th International Conference on Computing and Machine Intelligence, ICMI 2026 • Conference Paper • 2026 • DOI: 10.1109/ICMI68585.2026.11539925

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Abstract

Penalty kicks are among the most decisive and pressure-filled moments in football, often shaping the outcome of matches. Their complexity lies in the split-second decisions made by both kicker and goalkeeper, which traditional statistical or biomechanical approaches struggle to fully capture. In this paper, we explore how Deep Reinforcement Learning (DRL) can optimize penalty kick strategies using the Google Research Football (GRF) environment. We trained agents with two algorithms, Proximal Policy Optimization (PPO) and Independent PPO (IPPO), to model realistic kicker-goalkeeper interactions. Performance was analyzed through goal success rates, goalkeeper saves, and decision heatmaps. The trained IPPO agents exhibit a goal success rate exceeding 85%, a notable increase compared to baseline strategies which uses PPO agents (~65%). Spatial heatmaps further

revealed a strong preference for low-corner shots, aligning with real-world tendencies. These findings show that DRL-trained agents can learn adaptive and effective penalty strategies, offering practical insights for football analytics, training, and tactical preparation. © 2026 IEEE.

Author keywords

Decision-Making; Football Simulation; GRF; PPO

Indexed keywords

Engineering controlled terms

Deep learning; Football; Optimization

Engineering uncontrolled terms

Comparatives studies; Decisions makings; Football simulation; Google research football; Google+; Heatmaps; Penalty kick; Policy optimization; Proximal policy optimization; Reinforcement learnings

Engineering main heading

Decision making

Funding details

Details about financial support for research, including funding sources and grant numbers as provided in academic publications.

Funding sponsor	Funding number	Acronym
Air Force Office of Scientific Research See opportunities by AFOSR	FA2386-25-1-4035	AFOSR
Air Force Office of Scientific Research See opportunities by AFOSR		AFOSR

Funding text

This material is based upon work supported by the Air Force Office of Scientific Research under award number FA2386-25-1-4035

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