Learngene: Inheritable Genes in Intelligent Agents (Abstract Reprint)

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Abstract

Biological intelligence has driven significant progress in artificial intelligence (AI), but a critical gap remains: biological systems inherit innate abilities from genes, with brains initialized by blueprints refined over 3.5 billion years of evolution, while machines rely heavily on inefficient, data-driven learning from scratch. This gap arises from the lack of a genetic mechanism in machines to transfer and accumulate inheritable knowledge across generations. To bridge this gap, we propose learngenes, network fragments that act as inheritable 'genes' for machines. Unlike conventional knowledge transfer methods, learngenes enable efficient and universal knowledge transfer by selectively encapsulating task-agnostic knowledge. To facilitate the transfer and accumulation of task-agnostic knowledge across generations, we introduce Genetic Reinforcement Learning (GRL), a framework that simulates the learning and evolution of organisms in intelligent agents following Lamarckian principles. Through GRL, we identify learngenes as network fragments within agents' policy networks, equipping newborn agents with innate abilities for rapid adaptation to novel tasks. We demonstrate the advantages of learngene-based knowledge transfer over evolution-based search and traditional pre-trained models, and show how learngenes evolve through the accumulation of task-agnostic knowledge. Overall, this work establishes a novel paradigm for knowledge transfer and model initialization in AI, offering new possibilities for more adaptive, efficient, and scalable learning systems.

References

Feng, F.; Wang, J.; Yang, X.; and Geng, X. 2025. Learngene: Inheritable 'Genes' in Intelligent Agents. *Artificial Intelligence*, 348: 104421.