From Availability Heuristics to Causal Reasoning: A Neuro-Symbolic Cognitive Prosthetic for Long-Tail Clinical Decision Making

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Abstract

In the long tail of precision medicine, rare case exemplars are scarce, forcing clinicians toward slow, resource-intensive "System 2" reasoning. Large Language Models may help, but they often suffer from a fluency-factuality trade-off, producing plausible yet hallucinated clinical guidance without logical grounding. To address these dual inefficiencies, we propose the NeuroCR, a neuro-symbolic cognitive prosthetic modeled after Dual Process Theory. Its architecture synergizes an implicit associative memory (System 1) with an explicit causal reasoning module (System 2). Crucially, we introduce a "Semantic Schema Integration" algorithm to solve the Symbol Grounding Problem for heterogeneous clinical data, and a "Metacognitive Gating" mechanism to dynamically arbitrate between retrieval and reasoning. Evaluations on rare somatic mutations demonstrate that NeuroCR achieves a 140-fold speedup while preventing hallucinations through topological constraints. This work suggests that AI should not merely automate decisions but serve as a transparent scaffold for high-stakes human reasoning.

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