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Neuro-Symbolic AI for Formalized Reasoning and Real-Time Explainability in Autonomous System

S. Manjith¹, S. Taraka Soma Sekhara Sai Mani Krishna², K. Surya Santhosha Sai Dhaarani³, P. Koushik⁴, P. Koti Gnaneshwar⁵, K. Vishnuvardhan Reddy⁶, G. Hari Narayana⁷

UG Student, Department of CSE^{1,2,3,4,5,6,7} GITAM (Deemed to be University), Visakhapatnam, India

Abstract: Autonomous systems have become more prevalent in areas such as self-driving vehicles, aerial drones, and service robotics, the need for systems that make not only accurate but also understandable decisions has grown significantly. While deep learning has enabled major advances in perception and control, these models often operate as opaque black boxes, offering little insight into how or why specific decisions are made. This lack of transparency poses real risks, especially in safety-critical applications where human oversight, accountability, and trust are essential. In this work, we propose a Neuro-Symbolic AI framework that combines neural networks with symbolic reasoning to support both formalized decision-making and real-time explainability in autonomous systems. The neural component handles low-level perception tasks, while the symbolic layer captures high-level domain knowledge and reasoning rules. By integrating these two paradigms, the system can make informed decisions grounded in logical structures, while still benefiting from the flexibility of learning from data. To evaluate the framework, we conduct experiments in simulated driving environments using the CARLA simulator. The results demonstrate that our approach not only maintains competitive performance but also provides interpretable reasoning paths for its actions. This work contributes to the ongoing effort to design autonomous systems that are not only intelligent and adaptive, but also understandable and safe.

Keywords: Neuro-Symbolic AI, Explainable Artificial Intelligence (XAI), Autonomous Systems, Formalized Reasoning, Hybrid Intelligence Models, Real-Time Decision Makingmption

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