Integrating Symbolic Reasoning into Neural Generative Models for Design Generation

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Abstract

Design generation requires tight integration of neural and symbolic reasoning, as good design must meet explicit user needs and honor implicit rules for aesthetics, utility, and convenience. Current automated design tools driven by neural networks produce appealing designs, but cannot satisfy user specifications and utility requirements. Symbolic reasoning tools, such as constraint programming, cannot perceive low-level visual information in images or capture subtle aspects such as aesthetics. We introduce Spatial Reasoning Integrated Generator (SPRING) for design generation. SPRING embeds a neural and symbolic integrated spatial reasoning module inside the deep generative network. The spatial reasoning module samples the set of locations of objects to be generated from a backtrack-free distribution. This distribution modifies the implicit preference distribution, which is learned by a recursive neural network to capture utility and aesthetics. Sampling from the backtrack-free distribution is accomplished by a symbolic reasoning approach, SampleSearch, which zeros out the probability of sampling spatial locations violating explicit user specifications. Embedding symbolic reasoning into neural generation guarantees that the output of SPRING satisfies user requirements. Furthermore, SPRING offers interpretability, allowing users to visualize and diagnose the generation process through the bounding boxes. SPRING also handles novel user specifications not encountered during its training with zero-shot constraint transfer. Quantitative evaluations and a human study show that SPRING outperforms baseline generative models, delivering high design quality and better meeting user specifications.

References

Jacobson, M. J.; and Xue, Y. 2025. Integrating symbolic reasoning into neural generative models for design generation. *Artificial Intelligence*, 339: 104257.