Experimental Investigations into Graph Grammar Evolution

by

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Abstract

Artificial and natural instances of networks are ubiquitous, and many problems of practical interest may be formulated as questions about networks. Determining the optimal topology of a network is pertinent to many domains. Evolutionary algorithms constitute a well-established optimisation method, but they scale poorly if applied to the combinatorial explosion of possible network topologies. Generative representation schemes aim to overcome this by facilitating the discovery and reuse of design dependencies and allowing for adaptable exploration strategies. Biological embryogenesis is a strong inspiration for many such schemes, but the associated complexities of modelling lead to impractical simulation times and poor conceptual understanding. Existing research also predominantly focuses on specific design domains such as neural networks.

This thesis seeks to define a simple yet universally applicable and scalable method for evolving graphs and networks. A number of contributions are made in this regard. We establish the notion of directly evolving a graph grammar from which a population of networks can be derived. Compact cellular productions that form a hypergraph grammar are optimised by a novel multi-objective evolutionary design system called G/GRADE. A series of empirical investigations are then carried out to gain a better understanding of graph grammar evolution. G/GRADE is applied to four domains: symbolic regression, circuit design, neural networks, and telecommunications. We compare different strategies for composing graphs from randomly mutated productions and examine the relationship between graph grammar diversity and fitness, presenting both the use of phenotypic diversity objectives and an island model to improve this. Additionally, we address the issue of bloat and demonstrate how concepts from swarm intelligence can be applied to production selection and mutation to improve grammatical convergence. The results of this thesis are relevant to evolutionary research into networks and grammars, and the wide applicability and potential of graph grammar evolution is expected to inspire further study.

Certification

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Martin Holger Luerssen

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