Evolution in nature has designed countless solutions to innumerable interconnected problems, giving birth to the impressive array of complex modern life observed today. Inspired by this success, the practice of evolutionary computation (EC) abstracts evolution artificially as a search operator to find solutions to problems of interest primarily through the adaptive mechanism of survival of the fittest, where stronger candidates are pursued at the expense of weaker ones until a solution of satisfying quality emerges. At the same time, research in open-ended evolution (OEE) draws different lessons from nature, seeking to identify and recreate processes that lead to the type of perpetual innovation and indefinitely increasing complexity observed in natural evolution. New algorithms in EC such as MAP-Elites and Novelty Search with Local Competition harness the toolkit of evolution for a related purpose: finding as many types of good solutions as possible (rather than merely the single best solution). With the field in its infancy, no empirical studies previously existed comparing these so-called quality diversity (QD) algorithms.

This dissertation (1) contains the first extensive and methodical effort to compare different approaches to QD (including both existing published approaches as well as some new methods presented for the first time here) and to understand how they operate to help inform better approaches in the future. It also (2) introduces a new technique for encoding neural networks for evolution with indirect encoding that contain multiple sensory or output modalities. Further, it (3) explores the idea that QD can act as an engine of open-ended discovery by introducing an expressive platform called Voxelbuild where QD algorithms continually evolve robots that stack blocks in new ways. A culminating experiment (4) is presented that investigates evolution in Voxelbuild over a very long timescale. This research thus stands to advance the OEE community’s desire to create and understand open-ended systems while also laying the groundwork for QD to realize its potential within EC as a means to automatically generate an endless progression of new content in real-world applications.

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The public is welcome to attend.