

Generative Model-based Large-scale Dynamic Multiobjective Optimization

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Abstract

Large-scale, dynamic multi-objective optimization problems (LSDMOPs) extend traditional DMOPs into high-dimensional decision spaces, reflecting the growing complexity of real-world dynamic systems under expected or unanticipated environmental changes. A typical example is the economic control of gas transportation in large-scale pipeline network, which involve hundreds or even thousands of decision variables, representing pipeline node pressures, compressor power settings, and valve operations. The system is simultaneously affected by various time-varying factors, such as consumer demand, market fluctuation, environmental temperature and humidity. In such contexts, algorithms are required to quickly find optimal solutions after each environment change, maintaining supply-demand balance while minimizing energy consumption. In practice, there are many more such examples, including dynamic resource allocation of 5G networks in dense urban environments, UAV swarm dispatch in a disaster relief scenario, and large-scale dynamic vehicle routing planning, just to name a few. However, the effectiveness of existing dynamic multi-objective evolutionary algorithms is severely limited for LSDMOPs, due to inadequate training data, predictions in unknown environments, and large-scale dynamic search spaces. To address these challenges, we propose a diffusion learning-based evolutionary framework, inspired by the intrinsic analogy between iterative evolution of optimization search and stepwise denoising in diffusion learning. Specifically, a new training paradigm is designed to learn the changing patterns of optimal regions in dynamic fitness landscapes. It achieves this by using populations' evolutionary trajectories from initial solutions towards Pareto-optimal solutions across historical environments as rich supervised training data. In addition, we introduce a trajectory alignment loss which encourages the stepwise denoising process to conform to the true population evolutionary behaviors in terms of spatial exploration, convergence trends, and boundary adaptation. The trained model can gradually control denoising direction and intensity using predefined conditions, allowing it to generate optimization paths from random noise toward Pareto-optimal solutions for a new environment. Along with an adversarial autoencoder-based large-scale dynamic multi-objective evolutionary framework and a large language model-based large-scale dynamic multi-objective evolutionary framework, we will assess how deep generative modeling techniques and large-scale multi-objective evolutionary algorithms can be seamlessly integrated to solve large-scale DMOPs effectively and efficiently. Experimental results on a typical dynamic multi-objective test suite with problem settings from 10 to 1,000 dimensions demonstrate that the optimization performance of the proposed framework outperforms existing state-of-the-art designs. Especially in large-scale scenarios, the proposed framework is considered superior in terms of solution quality and computational efficiency.



Gary G. Yen was an associate editor of the IEEE Transactions on Neural Networks, IEEE Transactions on Evolutionary Computation, IEEE Transactions on Emerging Topics on Computational Intelligence, and IEEE Control Systems Magazine during 1994-1999, and of the IEEE Transactions on Control Systems Technology, IEEE Transactions on Systems, Man and Cybernetics (Parts A and B) and IFAC Journal on Automatica and Mechatronics during 2000-2010. He is currently serving as an associate editor for the IEEE Transactions on Cybernetics and IEEE Transactions on Artificial Intelligence. Gary served as Vice President for the Technical Activities, IEEE Computational Intelligence Society in 2004-2005 and was the founding editor-in-chief of the IEEE Computational Intelligence Magazine, 2006-2009. He was elected to serve as the President of the IEEE Computational Intelligence Society in 2010-2011 and is elected as a Distinguished Lecturer for the term 2012-2014, 2016-2018, 2021-2023, and 2025-2027. He received Regents Distinguished Research Award from OSU in 2009, 2011 Andrew P Sage Best Transactions Paper award from IEEE Systems, Man and Cybernetics Society, 2013 Meritorious Service award from IEEE Computational Intelligence Society and 2014 Lockheed Martin Aeronautics Excellence Teaching award. He is a Fellow of IEEE, IET and IAPR.