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**Tutorial title:** Distributed Evolutionary Computation for Multi-Agent Systems: Advances and Applications

Tutorial abstract

With the rapid advancement of technologies such as IoT, edge computing, and cloud services, distributed systems have become widely prevalent across various domains. Optimization problems in distributed systems pose a great challenge to traditional optimization algorithms due to data distribution, conflicting objectives, etc. In recent years, some researchers have focused on developing distributed evolutionary computation (DEC) methods, tackling the challenges of data distribution and objective conflict in distributed optimization problems.

The tutorial is organized into four parts. In Part 1, we introduce three major types of distributed optimization problems along with their applications. Part 2 delves into consensus-based distributed evolutionary computation, presenting recent advances in consensus mechanisms for multi-agent systems, including techniques for multi-agent swarm optimization and evolution strategies. We also illustrate these concepts with a real-world application in multi-sensor cooperative localization for wireless sensor networks. Part 3 covers data-driven distributed evolutionary computation, focusing on data-intensive DEC approaches such as edge-cloud co-evolutionary algorithms and crowd-sourcing optimization, along with applications in distributed machine learning and feature selection. Finally, we conclude the topic and discuss the future directions. By combining theoretical foundations with real-world applications, this tutorial offers participants a well-rounded perspective on DEC, showcasing its potential and practicality for distributed systems.

**Tutorial keywords:** Distributed Optimization; Evolutionary Computation; Multi-agent Systems; Data-driven Optimization

Topic overview

With the rapid advancement of technologies such as IoT, edge computing, and cloud services, distributed systems have become widely prevalent across various fields, such as wireless sensor networks, smart grids, and large-scale machine learning frameworks. These emerging distributed systems bring about numerous pressing optimization challenges, such as task allocation, resource management, and parameter tuning, that demand efficient and scalable solutions. Evolutionary computation (EC), as a class of powerful and efficient black-box optimization methods, holds significant potential to address these challenges effectively. However, in many distributed systems, data is often stored in a decentralized manner due to reasons such as privacy constraints, communication limitations, or resource availability. This distributed nature of data introduces unique challenges for evolutionary algorithms, which must now account for factors like data distribution, objective distribution, and dimension distribution.

Recently, some researchers have focused on developing distributed evolutionary computation (DEC) methods tailored for distributed systems, considering unique characteristics such as data distribution, objective distribution, and dimension distribution. This tutorial will present a comprehensive introduction to two major branches of DEC research: (1) Multi-Agent-Consensus-Based Distributed Evolutionary Computation. This class of studies focus on how to develop DEC methods to achieve the cooperation and consensus of multi-agent systems. Usually, the local objectives of agents are conflicting to the global objective of the whole system. Therefore, it is necessary and challenging to design cooperative methods or mechanisms for DEC, so as to strike balance among the local objectives of multiple agents. (2) Data-Driven Distributed Evolutionary Computation. This class of studies focus on how to optimize an optimization problem when the data is distributed in multiple nodes. This class of methods is especially important when there are characteristics such as data heterogeneity, non-independent and identically distributed, noise, and privacy protection, etc. In addition to theoretical research, we also provide introduction about related real-world applications to show the practical significance of this tutorial.

Outline of the tutorial structure, with time allocation and distribution of work

The 2 hours tutorial will consist of the following parts:

1. **An introduction of distributed optimization problems and the applications [25 mins]**
   1. Data-distributed optimization problems
   2. Objective-distributed optimization problems
   3. Dimension-distributed optimization problems
2. **Recent advances of multi-agent-consensus-based distributed evolutionary computation [35 mins]**
   1. Multi-agent swarm optimization with adaptive internal and external learning
   2. Multi-agent evolution strategies with cooperative cumulative step adaption
   3. The application on multi-sensor cooperative localization in wireless sensor networks

Break [5 mins]

1. **Recent advances of data-driven distributed evolutionary computation [40 mins]**
   1. Edge-Cloud co-evolutionary algorithms for distributed data-driven problems
   2. Crowd-sourcing evolutionary computation for distributed optimization
   3. The application on distributed machine learning and feature selection
2. **Conclusion and Future Directions [15 mins]**

Short Bio

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**Wei-Neng Chen** received the bachelor’s and Ph.D. degrees in computer science from Sun Yat-sen University, Guangzhou, China, in 2006 and 2012, respectively. Since 2016, he has been a Full Professor with the School of Computer Science and Engineering, South China University of Technology, Guangzhou. He has coauthored over 100 international journal and conference papers, including more than 70 papers published in the IEEE TRANSACTIONS journals. His current research interests include computational intelligence, swarm intelligence, network science, and their applications. Dr. Chen was a recipient of the IEEE Computational Intelligence Society Outstanding Dissertation Award in 2016 and the National Science Fund for Excellent Young Scholars in 2016. He was also a Principle Investigator of the National Science and Technology Innovation 2030—the Next Generation Artificial Intelligence Key Project. He is currently the Vice-Chair of the IEEE Guangzhou Section, and the Chair of IEEE SMC Society Guangzhou Chapter. He is also a Committee Member of the IEEE CIS Emerging Topics Task Force. He serves as an Associate Editor for the IEEE TRANSACTIONS ON NEURAL NETWORKS AND LEARNING SYSTEMS and the Complex and Intelligent Systems.

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**Feng-Feng Wei** received the bachelor’s degree in computer science and technology from the South China University of Technology, Guangzhou, China, in 2019, where she is currently pursuing the Ph.D. degree in computer science and technology with the School of Computer Science and Engineering. Her current research interests include swarm intelligence, evolutionary computation, distributed optimization, edge–cloud computing, and their applications on expensive optimization in real-world problems.

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**Qiang Yang** received his M. S. degree and Ph. D. degree from Sun Yat-sen University, Guangzhou, China, in 2014 and 2019, respectively. Currently, he is an associated professor with the School of Artificial Intelligence, Nanjing University of Information Science and Technology, Nanjing, China. His current research interests include evolutionary computation algorithms and their applications on real-world problems. So far, he specifically works on large scale optimization algorithms, multimodal optimization algorithms, distributed evolutionary algorithms and their applications on real-world problems, like intelligent transportation, logistics scheduling optimization and smart weather.