

Theory of Swarm Intelligence

Tutorial Abstract for WCCI 2014

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Social animals as found in fish schools, bird flocks, bee hives, and ant colonies are able to solve highly complex problems in nature. This includes foraging for food, constructing astonishingly complex nests, and evading or defending against predators. Remarkably, these animals in many cases use very simple, decentralized communication mechanisms that do not require a single leader. This makes the animals perform surprisingly well, even in dynamically changing environments. The collective intelligence of such animals is known as swarm intelligence and it has inspired popular and very powerful optimization paradigms, including ant colony optimization (ACO) and particle swarm optimization (PSO).

The reasons behind their success are often elusive. We are just beginning to understand when and why swarm intelligence algorithms perform well, and how to use swarm intelligence most effectively. Understanding the fundamental working principles that determine their efficiency is a major challenge.

This tutorial will give a comprehensive overview of recent theoretical results on swarm intelligence algorithms, with an emphasis on their efficiency (runtime/computational complexity). In particular, the tutorial will show how techniques for the analysis of evolutionary algorithms can be used to analyze swarm intelligence algorithms and how the performance of swarm intelligence algorithms compares to that of evolutionary algorithms. The results shed light on the working principles of swarm intelligence algorithms, identify the impact of parameters and other design choices on performance, and thus help to use swarm intelligence more effectively.

The tutorial will be divided into a first, larger part on ACO and a second, smaller part on PSO. For ACO we will consider simple variants of the MAX-MIN ant system. Investigations of example functions in pseudo-Boolean optimization demonstrate that the choices of the pheromone update strategy and the evaporation rate have a drastic impact on the running time. We further consider the performance of ACO on illustrative problems from combinatorial optimization: constructing minimum spanning trees, solving shortest path problems with and without noise, and finding short tours for the TSP.

For particle swarm optimization, the tutorial will cover results on PSO for pseudo-Boolean optimization as well as a discussion of theoretical results in continuous spaces.