Evolutionary Multi-Objective Optimization: Current and Future Research Trends

Plenary Talk

Carlos A. Coello Coello
CINVESTAV-IPN, Depto. Computación
Av. IPN No. 2508, San Pedro Zacatenco
México, D.F. 07360, Mexico
ccoello@cs.cinvestav.mx

During the last few years, there has been an increasing interest in using heuristic search algorithms based on natural selection (the so-called "evolutionary algorithms") for solving a wide variety of problems. As in any other discipline, research on evolutionary algorithms has become more specialized over the years, giving rise to a number of sub-disciplines. This talk deals with one of these emerging sub-disciplines that has become very popular due to its wide applicability: evolutionary multi-objective optimization (EMOO).

EMOO refers to the use of evolutionary algorithms (or even other biologically-inspired metaheuristics) to solve problems with two or more (often conflicting) objectives. Unlike traditional (single-objective) problems, multi-objective optimization problems normally have more than one possible solution (the so-called Pareto optimal set, whose vectors are called nondominated and whose image is called the Pareto front). Even the notion of optimum is different in this case, since the main aim is not to find one globally optimum solution, but the best possible trade-offs or compromise solutions (i.e., solutions in which it is not possible to improve one objective without worsening another one). This is called Pareto optimality, which is the most popular definition of *optimum* currently adopted in multi-objective optimization. Thus, traditional evolutionary algorithms (e.g., genetic algorithms or evolution strategies) need to be modified in order to deal with such problems, since in their original form they will tend to converge to a single solution (i.e., the fittest in the population) after a sufficiently large number of iterations. The main change required involves modifying the selection process, which must be blocked such that several solutions can be retained in the population during a run. This has as its goal to be able to generate, after a single run, several elements of the Pareto optimal set, rather than only one.

This talk will provide a general overview of the EMOO field, from a historical view, focused, mainly, around the major algorithmic achievements in the field. Thus, at the beginning, the first generation multi-objective evolutionary algorithms (MOEAs) will be discussed. Such algorithms were relatively simple, normally not too efficient, were non-elitist and remained in use during about 10 years. Elitism refers to retaining the best solutions found in one iteration into the next population. Such a concept is more complicated in EMOO, since all the nondominated solutions are equally good and, in theory, all of them must be retained. In practice, however, elitist mechanisms are normally bounded, limiting the number of nondominated solutions that are maintained, and giving rise to the another key mechanism of modern MOEAs: diversity estimators. A diversity estimator tries to promote the search towards little explored regions of the search space, by penalizing solutions that are in very crowded regions, and rewarding those lying in isolated regions. The use of elitism is important, since it has been proved that such mechanism is required in order to guarantee convergence of a MOEA. Nowadays, elitism is normally implemented through the use of an external archive that stores the (globally) nondominated solutions generated by a MOEA. However, other elitist mechanisms are also possible.

Towards the end of the 1990s, elitist MOEAs started to become popular, and new, more elaborate, efficient and effective MOEAs were developed. The most representative approaches from these two groups (non-elitist and elitist MOEAs) will be briefly described in this talk, emphasizing their key components.

In the final part of the talk, some of the current applications of MOEAs will be mentioned. Then, the main current challenges faced by EMOO researchers will be briefly discussed (e.g., problems having many objectives, mechanisms to deal with very expensive objective functions, etc.), aiming to motivate practitioners, researchers and students to get interested in this exciting field that has already attracted the interest of a wide number of people from diverse disciplines around the world.