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A continuous-state cellular automata algorithm for global optimization

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A B S T R A C T

Cellular automata are capable of developing complex behaviors based on simple local interactions between their elements. Some of these characteristics have been used to propose and improve metaheuristics for global optimization; however, the properties offered by the evolution rules in cellular automata have not yet been used directly in optimization tasks. Inspired by the complexity that various evolution rules of cellular automata can offer, the continuous-state cellular automata algorithm is proposed. In this way, the algorithm takes advantage of different evolution rules to maintain a balance that maximizes the exploration and exploitation properties in each iteration. The efficiency of the algorithm is proven with 48 test problems widely used in the literature, 4 engineering applications that were also used in recent literature, and the design of adaptive infinite-impulse response filters, with the reference functions of 10 full-order filters being tested. The numerical results prove its competitiveness in comparison with state-of-the-art algorithms. The source codes of the proposed algorithm are publicly available at https://github.com/juanseck/CCAA.git.

1. Introduction

Nowadays, engineering problems have become increasingly complex due to the changes in the numbers and relationships of the variables that define them. Under these conditions, it is very difficult, or even impossible, to apply traditional mathematical methods to solve these problems quickly and satisfactorily. Conventional methods face difficulties, such as convergence to local optima and the dependence of their correct convergence on the initial solution chosen, while attempting to solve complex problems. These methods also require that the problem being solved fulfills a series of mathematical properties such as convexity, continuity, and differentiability, which often leads to an excessive simplification of the problem (Sarker, Kamruzzaman, & Newton, 2003). In many cases, the methods based on mathematical programming such as the conjugate gradient and quasi-Newton methods are not suitable for solving multidimensional, multimodal, non-continuous, and non-differentiable problems (Jamil & Yang, 2013).

For this reason, new optimization methods have been proposed, such as metaheuristics, which are high-level algorithms capable of finding adequate solutions. Although it cannot be demonstrated that metaheuristic algorithms reach an optimal value, they can generate satisfactory results in a reasonable time (Kumar & Davim, 2020).

Metaheuristic algorithms are of great relevance because, in general, they are easy to implement and their operation is based on simple concepts that do not require information regarding the gradient of the function to be optimized. A good metaheuristic algorithm can escape from local optima in multiple dimensions and be used in a wide range of optimization, design, and parameter identification problems.

For that purpose, metaheuristic algorithms must perform in an efficient and balanced way the exploration of the solution space and the exploitation of promising areas of said space. Since these actions can conflict and leave the algorithm trapped in a local minimum, maintaining the right balance between the two processes is essential to obtain a metaheuristic algorithm that calculates good solutions, avoiding stagnation or premature convergence towards local minima.

In this work, a new metaheuristic algorithm based on the neighborhood concept and evolution rules of cellular automata is proposed for the global optimization of problems defined in multiple dimensions. As this algorithm uses continuous variables, it has been named the continuous-state automata algorithm (CCAA).

The algorithm defines a set of initial solutions, each of which generates a random neighborhood of possible new solutions to improve the

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