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Cellular Genetic Algorithm with Density Dependence for Dynamic Optimization Problems

Hao Chen [1], Ming Li [2, +] and Xi Chen [2]

[1] College of Automation Engineering, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China

[2] Key Laboratory of Nondestructive Test, Nanchang Hangkong University, Nanchang 330063, China

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Abstract. For dynamic optimization problems, the aim of an effective optimization algorithm is both to find the optimal solutions and to track the optima over time. In this paper, we advanced two kinds of cellular genetic algorithms inspired by the density dependence scheme in ecological system to solving dynamic optimization problems. Two kinds of improved evolution rules are proposed to replace the rule in regular cellular genetic algorithm, in which null cells are considered to the foods of individuals in population and the maximum of living individuals in cellular space is limited by their food. Moreover, in the second proposed rule, the competition scheme of the best individuals within the neighborhoods of one individual is also introduced. The performance of proposed cellular genetic algorithms is examined under three dynamic optimization problems with different change severities. The computation results indicate that new algorithms demonstrate their superiority respectively on both convergence and diversity.

Keywords: cellular genetic algorithm, dynamic optimization, density dependence scheme

1. Introduction

Most of the optimization problems in real world are dynamic optimization problems (DOPs). Evolutionary algorithms (EAs) have been widely and successfully applied to solve static optimization problems (SOPs). However, the evaluation function, design variables, and the constraints are not fixed in DOPs. Hence, for DOPs the aim of an effective optimization problem is not only to find the optimal solution but also to track the optima over time.

In recent years, there is a growing interest in studying evolutionary algorithms (EAs) for DOPs, and several approaches have been developed, such as increasing diversity after a change via hyper mutation [1] or random immigrants[2], maintaining diversity throughout the run [3,4], memory schemes [5,6], and multi-population approaches [7,8].

Cellular genetic algorithm (CGA) is a subclass of genetic algorithms (GAs); it is set up through an organic combination of evolutionary computation and cellular automata. In CGA, the population is arranged in a given grid, the evolution of each individual is restricted in its neighborhood, and each individual is only allowed to genetic operate with the individuals in its neighborhood. With the distributed arrangement, CGA has a good performance on maintaining genetic diversity which is important to find and approximate the dynamic optimum for DOPs. Hence, CGA is considered to be a significant and meaningful algorithm to solving DOPs.

The research on combining ideas from cellular automata with genetic algorithms began in Manderick and Spiessens's work [9]. Over the past decade or so, CGAs have been proven to be effective for solving many kinds of optimization problems from both classical and real world settings.

Many kinds of improved CGAs were proposed for optimizations. Kirley [10] introduced a novel evolutionary algorithm named cellular genetic algorithm with disturbances inspired by the nature of spatial interactions in ecological systems. Simoncini et al. [11] presented an anisotropic selection scheme for CGA, improved the performance by enhance diversity and control the selective pressure. Janson and Alba [12]

[+] Corresponding author. Tel.: +86-0791-386 3695; fax: +86-0791-386 3695.
E-mail address: limingniat@hotmail.com

proposed a hierarchical CGA, where the population structure was augmented with a hierarchy according to the fitness of individuals. Nebro et al [13] introduced an external archive in CGA to store the better solutions, the search experience contained in the archive were feed backed into algorithm though replacement strategy. Ishibuchi et al. [14] proposed a new CGA with two neighborhood structures: one for global elitism, the other for local competition among neighbors.

Besides, the theoretical research of CGAs is also active. Giacobini et al. [15] presented a theoretical study of the selection pressure in asynchronous CGAs with different evolution rules. Alba et al. [16] presented a comparative study of several asynchronous policies for updating the population in CGAs. Zhang [17] researched the evolution rules of optimization algorithm with cellular automata from the ability of life reproduction and the probability of survival.

In this paper we investigate an improved cellular genetic algorithm to solving DOPs. Inspired by density dependence scheme in the nature, we propose a new evolution rules. The paper is structured as follows. Section 2 reviews some related work on CGA. Section 3 introduces the regular CGA with evolution rules. In Section 4, two density dependence schemes are introduced, population control scheme is also discussed, and a cellular genetic algorithm with density dependence is proposed. Section 5 introduces the DOPs chosen and presents the results of proposed algorithm. Section 6 briefly expressed the conclusion of this paper.

2. Cellular Genetic Algorithm with Evolution Rules

2.1. Basic concepts

A cellular automaton can be denoted as $\boldsymbol{A} = (L_d, S, N_d, f)$ mathematically, in which $\boldsymbol{A}$ is a cellular automaton; L_d is the cellular space; S is the set of states of cell, each cell only has one state such as “living” or “dead”; N_d denotes the neighborhood of a cell such as Von. Neumann-type, Moore-type, Ex-Moore-type; f is the local transfer function which defines the state of the center cell by the states of its neighbors, and can be called evolution rule.

Fig.1 shows the Moore-type in grid, in which a cell in the small black square is the center cell; cells within two squares are the neighborhood of the center cell; the grey means living, contrarily, the white means dead. In this paper, the proposed algorithm uses this type.

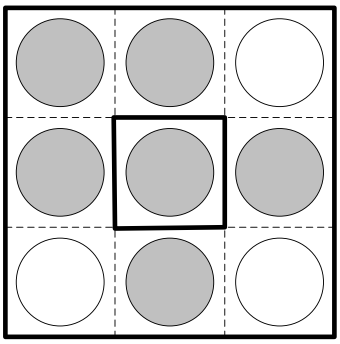

Fig. 1: Moore-type in regular grid

2.2. Cellular genetic algorithm with evolution rule

The pseudo-code of cellular genetic algorithm with evolution rule is shown in Fig.2. In this algorithm, each living individual only interacts and genetic operates with individuals in its neighborhood. The fitness value of offspring individuals will be calculated, if an offspring is better than the center cell individual, the old center one will be replaced during the next generation. After the genetic operation, state of each individual will be update by the evolution rule.