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Incoherent beam combining based on imperialist competitive algorithm

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ABSTRACT

Incoherent beam combining is an extremely efficient method to achieve high-energy laser output. In this paper, we present the numerical study on the incoherent beam combining using imperialist competitive algorithm (ICA). The feasibility is validated by the simulation of incoherent beam combining system using the ICA under the conditions of free space. The capability of ICA under the different condition of atmosphere turbulence is numerically studied by simulation. It is revealed that ICA is a feasible means for beam combining system even under the condition of strong turbulence. Further, the performance of ICA for incoherent beam combining is compared with a widely used stochastic parallel gradient descent (SPGD) algorithm. The ICA have a small number of iterations and satisfactory correction effect compared with SPGD algorithm. Therefore, the ICA is a promising method for beam combining system.

1. Introduction

Beam combining is an important way for fiber laser to develop toward the higher power. It can effectively solve the limitation of laser medium nonlinear effect and optical element technology [1]. Fiber lasers can be combined by coherent, spectral or incoherent means [2–6]. Incoherent beam combining which is achieved by the individual fiber laser beam overlapping at a target plane, has a number of advantages, such as simple structure and not requiring controlling the beam phase like coherent beam combining (CBC) [7–9]. Therefore, the current, incoherent beam combining is simple and effective way to obtain high power output.

A new optimization algorithm—imperialist competitive algorithm, which originates in a simulation of the social political process of imperialism and imperialistic competition, was proposed by Atashpaz-Gargari and Lucas in 2007 [10]. At present, there are a number of scholars to improve the ICA and to solve the practical problems in various fields, such as solving scheduling problems in industrial production, solving optimization problems in communication systems, and designing controllers for industrial systems [11–13]. In 2014, ICA was used for phase aberration correction in a wavefront sensorless adaptive optical system by Yazdani [14]. The simulation results indicate that ICA has approving correction capability. Nevertheless, there are few articles that report application of the ICA in beam combining.

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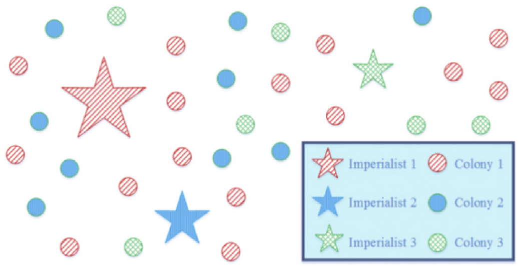

Fig. 1. Creating the initial empires. The imperialist with more colonies has bigger ⋆ mark.

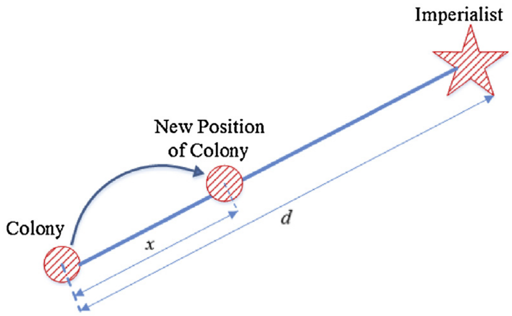

Fig. 2. Assimilation policy. The colony moves toward its imperialist.

In this paper, we present the numerical study on incoherent beam combining using the ICA. This paper is organized as follows: in Section 2, the basic principle of the ICA is described; In Section 3, the system setup and technique details for incoherent beam combining using the ICA are illustrated. Moreover, the performances of incoherent beam combining using the ICA under the conditions of free space and atmospheric turbulence are simulated and analyzed. A comparison is made between the SPGD algorithm and the ICA in Section 4. The summary is given in Section 5.

2. Imperialist competitive algorithm (ICA)

The ICA is a mathematical model that is established by simulating the social political process of imperialism and imperialistic competition. The procedures of the basic ICA are described as follows:

Generating Initial Empires. The initial countries of size N_c are randomly produced. N_{imp} of the most powerful countries are selected as the imperialists, and the rest (N_{col} = N_c - N_{imp}) are the colonies. Colonies distribute among the imperialists depending on their powers. The detailed method of allocation refers to Eqs. (1)–(3).

$$J_n = J_{imp.n} - \min\{J_{col.i}\} \tag{1}$$

$$P_n = \left| \frac{J_n}{\sum_{i=1}^{N_{imp}} J_i} \right| \tag{2}$$

$$NC_n = round\{P_n(N_c - N_{imp})\} \tag{3}$$

Where $J_{imp.n}$ is the cost of the nth imperialist and $J_{col.i}$ is the cost of its ith colony; J_n is the normalized cost; P_n is the normalized power; NC_n is the initial number of colonies of nth empire. Fig. 1 displays that bigger empires have bigger ⋆ mark, while weaker ones have smaller.

Assimilation Policy. Imperialists start to improve their colonies by the assimilation policy, which make their colonies move to them along optimization axes. Fig. 2 shows that the colony moves toward its imperialist by x units.

In order to improve the global searching ability and to prevent the local extremum of the algorithm, a small part of the colonies will undergo reforms. Fig. 3 illustrates the reform for a two-dimensional optimization problem.

Colonies Uprising. Some colonies may reach a position with higher cost than that their empire after assimilation for all colonies and revolution for a percentage of them. In such a case, the positions of the colonies and that their imperialist are exchanged. Fig. 4 describes colony against empire.