Chapter 11
Nature–Inspired–Based Multi–Objective Hybrid Algorithms to Find Near–OGRs for Optical WDM Systems and Their Comparison

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ABSTRACT

Nature-inspired-based approaches are powerful optimizing algorithms to solve the NP-complete problems having multiple objectives. In this chapter, two nature-inspired-based multi-objective optimization algorithms (MOAs) and their hybrid forms are proposed to find the optimal Golomb rulers (OGRs) in a reasonable time. The OGRs can be used as a channel-allocation algorithm that allows suppression of the four-wave mixing crosstalk in optical wavelength division multiplexing systems. The presented results conclude that the proposed MOAs outperforms the existing conventional classical and nature-inspired-based algorithms to find near-OGRs in terms of ruler length, total occupied optical bandwidth, bandwidth expansion factor, computation time, and computational complexity. In order to find the superiority of proposed MOAs, the performances of the proposed algorithms are also analyzed by using statistical tests.

INTRODUCTION

Due to the high degree of dimensionality, complexities, and nonlinearities, finding optimal solutions to any problem with multi–objective are very time consuming and tough. To solve the multi–objective problems, numerous nature–inspired based multi–objective optimization algorithms (MOAs) are being formulated by Abbass and Sarker (2002), Deb (2001), and Yang et al., (2014). Nature–inspired based MOAs can have several conflicting solutions instead of having single optimal solution, making it

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impossible to use any single design option without compromise. Pareto optimal solution called Pareto front (Koziel and Yang, 2011; Yang et al., 2014) is the best compromise optimal solutions from several solutions that cannot be dominated as no objective can be better without making some other objective worse. The MOAs either search the Pareto optimal solutions or solutions near to Pareto front to provide flexibility for the design engineer.

This chapter proposes the application of nature–inspired based multi–objective Big bang–Big crunch (MOBB–BC) algorithm, multi–objective Firefly algorithm (MOFA) and their modified hybrid forms, namely, modified MOBB–BC (M–MOBB–BC) algorithm, and modified MOFA (M–MOFA) to solve an NP–complete optimal Golomb ruler (OGR) problem (Babcock, 1953; Bloom and Golomb, 1977; Colannino, 2003; Distributed.net, 2017; Meyer and Papakonstantinou, 2009; Memarsadegh, 2013; Robinson, 1979; Shearer, 1990; Shearer, 1998) in optical wavelength division multiplexing (WDM) systems. The OGRs found their application as unequally spaced channel–allocation algorithm (USCA) in optical WDM systems to suppress one of the dominant nonlinear optical effects formulated in literatures (Aggarwal, 2001; Babcock, 1953; Chraplyvy, 1990; Forghieri et al., 1994; Kwong and Yang, 1997; Saaid, 2010; Singh and Bansal, 2013; Thing et al., 2004), i.e. four–wave mixing (FWM) crosstalk. The performance of the system can be improved if FWM crosstalk signals generation at the channel frequencies is avoided. If the frequency separation of any two channels in an optical WDM system is different from that of any other pair of channels, no FWM crosstalk signals will be generated (Aggarwal, 2001; Babcock, 1953; Chraplyvy, 1990; Saaid, 2010; Thing et al., 2004).

To suppress the FWM crosstalk, several USCAs have been proposed by Atkinson et al. (1986), Forghieri et al. (1995), Hwang and Tonguz (1998), Kwong and Yang (1997), Randhawa et al. (2009), Sardesai (1999), and Tonguz and Hwang (1998) with the limitation of increased bandwidth requirement as compared to equally spaced channel–allocation. This chapter proposes a bandwidth efficient USCA by taking into consideration near–OGRs (Babcock, 1953; Bloom and Golomb, 1977; Shearer, 1990; Thing et al., 2003) to suppress FWM crosstalk.

Cota et al. (2006), Galinier et al. (2001), Leitao, (2004), Rankin (1993), Robinson (1979), and Shearer (1990), presented numerous algorithms to solve OGR problem. Many authors has successfully realized the algorithms such as Tabu search (TS) (Cota et al., 2006), Memetic approach (MA) (Cota et al., 2006), Genetic algorithms (GAs) (Ayari et al., 2010; Bansal, 2014; Robinson, 2000; Soliday et al., 1995) and its hybridizations with TS (Ayari et al., 2010), hybrid evolutionary (HE) (Dotú and Hentenryck, 2005), Biogeography based optimization (BBO) (Bansal et al., 2011; Bansal, 2014), simple Big bang–Big crunch (BB–BC) (Bansal et al., 2013; Jyoti et al., 2016), simple Firefly algorithm (FA) (Bansal et al., 2014), multi–objective Bat algorithm (MOBA) (Ritu et al., 2016) and its modified forms (Bansal et al., 2017a; Bansal et al., 2017b), Cuckoo search algorithm (Bansal et al., 2014) and its hybridization (Bansal et al., 2017b; Kumari et al., 2016), and multi–objective Flower pollination algorithm and its hybridization (Bansal et al., 2017b; Jain et al., 2015) in finding near–OGRs. Therefore, nature–inspired based algorithms seem to be very effective solutions to such NP–complete problems. The proposed MOAs solve the bi–objective in OGR problem as optical WDM channel–allocation problem. The performances of the proposed algorithms are compared with the existing algorithms to find near–OGRs.