International Journal of Swarm Intelligence Research
Volume 13 • Issue 1

Engineering Design Optimization Using an Advanced Hybrid Algorithm

Pooja Verma, Indira Gandhi National Tribal University, Amarkantak, India *
Raghav P. Parouha, Indira Gandhi National Tribal University, Amarkantak, India

ABSTRACT

An advanced hybrid algorithm (haDEPSO) is proposed in this paper for engineering design optimization problems. It is integrated with suggested advanced differential evolution (aDE) and particle swarm optimization (aPSO). aDE introduced a novel mutation, crossover, and selection strategy to avoid premature convergence. And aPSO consists of novel gradually varying parameters to escape stagnation. So, convergence characteristic of aDE and aPSO provides different approximation to the solution space. Thus, haDEPSO achieves better solutions due to integrating merits of aDE and aPSO. Also, in haDEPSO, individual population is merged with other in a pre-defined manner to balance between global and local search capability. Proposed hybrid haDEPSO as well as its integrating components aDE and aPSO has been applied to five engineering design optimization problems. Numerical, statistical, and graphical experiments (best, worst, mean, and standard deviation plus convergence analysis) confirm the superiority of the proposed algorithms over many state-of-the-art algorithms.

KEYWORDS

Differential Evolution, Engineering Design Optimization, Global and Local Search, Gradually Varying Parameters, Hybrid Algorithm, Meta-Heuristic Algorithms, Particle Swarm Optimization

1. INTRODUCTION

Nowadays, most of the design optimization problems in engineering are turning out to be complicated due to involving mixed (discrete and continuous) variables under complex constraints. Generally, these problems are large scale non-linear constrained problems and hence cannot be solved by traditional methods efficiently. Presently, to overcome the drawbacks of conventional optimization methods, a bunch of optimization methods known as meta-heuristics algorithms (MAs) has been introduced. According to the mechanical differences the MAs can be categorized into four groups as follows- (i). **Swarm intelligence algorithms (SIAs):** inspired from behavior of social insects or animals like PSO (Particle Swarm Optimization) (Kennedy, & Eberhart, 1995), ABC (Artificial Bee Colony Algorithm) (Karaboga, & Basturk, 2007), FA (Firefly Algorithm) (Yang, 2009), CS (Cuckoo Search) (Yang & Deb, 2009), KH (Krill Herd) (Gandomi & Alavi, 2012), GWO (Grey Wolf Optimizer) (Mirjalili, Mirjalili, & Lewis 2014), DA (Dragonfly Algorithm) (Mirjalili, 2016), WOA (Whale Optimization Algorithm) (Gadekallu et al., 2020) etc. (ii). **Evolutionary algorithms (EAs):** inspired from biology like GA (Genetic Algorithm) (Davis, 1991) and DE (Differential Evolution) (Storn & Price, 1997) etc. (iii). **Physics-based algorithms (PBAs):** inspired by the rules governing a natural phenomenon such as HS (Harmony Search) (Geem, Kim, & Loganathan, 2001), GSA (Gravitational Search Algorithm) (Rashedi, Nezamabadi-pour, & Saryazdi, 2009), WCA (Water Cycle Algorithm)

DOI: 10.4018/IJSIR.2022010106 *Corresponding Author

(Eskandar, Sadollah, Bahreininejad, & Hamdi, 2012), WDO (Wind Driven Optimization) (RM et al. 2020) and so on. (iv). **Human behavior-based algorithms (HBAs):** inspired by a human being like TLBO (Teaching-learning-based optimization) (Rao, Savsani, & Vakharia, 2011), SAR (Search and rescue optimization) (Shabani, Asgarian, Gharebaghi, Salido, & Giret, 2019) etc.

Among many MAs, DE and PSO have been widely used in continuous/discrete, constrained as well as unconstrained optimization problems. DE has remarkable performance and becomes a powerful optimizer in the field of real-world problems. However, it has a few issues such as convergence rate and local exploitation ability. In order to overcome its shortcomings, lots of robust and effective DE has been designed in the literature (Yang, & Peng, 2019; Prabha, & Yadav, 2019; Liu, Ji, & Yang, 2019; Gui, Xia, Yu, Wu, Wu, Wei, & He, 2019; Li, Gu, Gong, & Ning, 2020; Hu, Hua, Lei, & Xiantian, 2020; Ben, 2020). Also, PSO has attracted attention to solving many complex optimization problems due to its efficient searchability and simplicity. However, the main drawback of the PSO is that it may easily get stuck at a locally optimal solution region. To overcome such issues many different modifications of the PSO proposed in the literature (Parouha, 2019; Hosseini, Hajipour, & Tavakoli, 2019; Kohler, Vellasco, & Tanscheit, 2019; Khajeh, Ghasemi, & Arab, 2019; Ang, Lim, Isa, Tiang, & Wong, 2020; Lanlan, Ruey, Wenliang, & Yeh, 2020; Xiong, Qiu, & Liu, 2020). Furthermore, a hybrid strategy is one of the main research directions to improve the performance of single algorithm (Maddikunta et al., 2020). Therefore, in order to enhance the performance of DE and PSO, lots of their hybrid algorithms are presented in the literature (Parouha, & Das, 2016; Mao, Xie, Wang, Handroos, & Wu, 2018; Tang, Xiang, & Pang, 2018; Too, Abdullah, & Saad, 2019; Dash, Dam, & Swain, 2019; Zhao, Zhang, Xie, & Meng, 2020). Nevertheless, to overcome their individual shortcomings, hybrid techniques are now more favored over their individual effort.

After extensive literature review on different variants of DE and PSO with their hybridization, following points are analyzed and motivated from them. (i). DE and PSO have complementary properties therefore their hybrids has gained prominence recently. To best of our knowledge, finding ways to combine DE and PSO is still an open problem. (ii). in DE mutation and crossover strategy with their associate control parameters utilized to produce the global best solution which is beneficial for improving convergence behavior. Therefore, in DE most appropriate strategies and their associated parameter values are considered a vital research study. (iii). performance of PSO greatly depends on its parameters like acceleration coefficients and inertia weight which guide particles to the optimum and balancing diversity respectively. Hence, many researchers have tried to modify control parameter of PSO to achieve better accuracy and higher speed.

Major contribution: encouraged by above observations and survey of literature, design an advanced hybrid *h*aDEPSO algorithm with the following suggested component for solving engineering design optimization problems. (i) an advanced differential evolution (aDE) where combination of novel mutation, crossover and selection strategy strategies with their associated parameter values are familiarized and (ii) an advanced particle swarm optimization (aPSO) which consists of novel gradually varying (decreasing and/or increasing) parameters. This paper is structured as follows: Section 2 briefed the basics of DE and PSO. Section 3 describes the proposed algorithms. Application of proposed algorithms is presented in Section 4. Section 5 concludes this study with future works.

2. BRIEF ON DE AND PSO

The basics of original DE and PSO are presented below.

2.1 DE (Differential Evolution)

After initialization, DE is conducted three main operations as follows.

Mutation: at iteration t , for each target vector (x_{ij}^{t}) a mutant vector (v_{ij}^{t}) is generated as follows.