A Seed-based Plant Propagation Algorithm: The Feeding Station Model

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1 Introduction

Plants rely heavily on the dispersion of their seeds to colonise new territories and to improve their survival [2]. There are a lot of studies and models of seed dispersion particularly for trees [1, 2]. Dispersion by wind and ballistic means are probably the most studied of all approaches. Although there are a lot of Nature-inspired algorithms for optimisation, [7], very few are based on plant propagation, particularly when seeds are involved. In this study we consider the way the strawberry plant uses seeds to propagate. Because of the way the seeds stick to the surface of the fruit, the strawberry, dispersion by wind or mechanical means is very limited. Animals, however, and birds in particular are the ideal agents of dispersion, [2]. Here, we consider each strawberry plant after it has flowered and produced fruit, as opening a feeding station to be attended by the potential seed dispersing agents, in this case birds and other animals. We then consider the appropriate probabilistic models of attendance of the stations (plants) and dispersion after feeding, and build around these models a meta-heuristic that can handle search over predefined spaces for optimising a given function.

2 SbPPA, the seed-based plant propagation algorithm

The Plant Propagation Algorithm (PPA) based on the way the strawberry plant propagates using runners, has been considered in [4, 5]. Here, we consider its counterpart which relies only on seed propagation, call it SbPPA (for Seed-based PPA). Basically, the strawberry plant attracts frugivores by offering them food. The frugivores, unwittingly, will help spread, potentially far and wide, the seeds, in this case, stuck to the fruit they have consumed. This, of course, helps the plant survival and success in terms of space occupancy. To capture this dispersion process, we take inspiration from a number of well studied situations such as feeding stations (restaurants !) for human beings. The key aspects to consider are the rate of arrival of the consumers, in this case the dispersing agents (frugivores) and the rate of service, in this case how long it takes for a bird, say, to pick a strawberry and swallow it. The basic queuing model, [3], in this case, assumes that arrival follows a Poisson distribution while service time follows an exponential distribution. It is easy to see how the Poisson distribution may fit here. It is also easy to see how the Lévy distribution may be relevant, [6]. It is less so when it comes to the exponential distribution, although some reasonable assumptions make it acceptable. Note that we are not trying to describe the general seed dispersion process here. What we are after is its simulation to fit our own requirements in terms of searching for a good approximate solution to our search/optimisation problem. This paper addresses the different issues related to which distributions are to be used and how. The key parameters that the queuing model generates and on which the new meta-heuristic is based, are the expected number of dispersing agents feeding on the crop produced by a number of plants, and the efficiency of the feeding station which is not restricted to a single plant.

3 Computational results

SbPPA has been implemented and tested on unconstrained and constrained optimization problems, some of which coming from design engineering. The same problems have also been solved with a number of well established meta-heuristics such as the Artificial Bee Colony (ABC) algorithm , the Particle Swarm Optimization (PSO) algorithm, the Firefly Algorithm (FF), the Hybridised Particle

Swarm and Artificial Bee Colony algorithm (HPA) and the Social Spider Optimization (SSO-C) algorithm. Some of the comparative results are recorded in the table below where significant results are marked '+' when superior, '-' when inferior and '≈' when about the same. On the whole, the results point to SbPPA as a serious meta-heuristic at least on the set of problems considered.

Table 1. Results obtained by SbPPA, HPA, PSO and ABC. All problems in this table are unconstrained.

Fun	Dim	Algorithm	Best	Worst	Mean	SD
5	6	ABC	(≈) -50.0000	(≈) -50.0000	(≈) -50.0000	(-) 0
		PSO	(≈) -50.0000	(≈) -50.0000	(≈) -50.0000	(-) 0
		HPA	(≈) -50.0000	(≈) -50.0000	(≈) -50.0000	(-) 0
		SbPPA	-50.0000	-50.0000	-50.0000	5.88E-09
6	10	ABC	(+) -209.9929	(+) -209.8437	(+) -209.9471	(+) 0.044
		PSO	(≈) -210.0000	(≈) -210.0000	(≈) -210.0000	(-) 0
		HPA	(≈) -210.0000	(≈) -210.0000	(≈) -210.0000	(+) 1
		SbPPA	-210.0000	-210.0000	-210.0000	4.86E-06
7	30	ABC	(+) 2.6055E-16	(+) 5.5392E-16	(+) 4.7403E-16	(+) 9.2969E-17
		PSO	(≈) 0	(≈) 0	(≈) 0	(≈) 0
		HPA	(≈) 0	(≈) 0	(≈) 0	(≈) 0
		SbPPA	0	0	0	0

Table 2. Results obtained by SbPPA , PSO, ABC, FF and SSO-C. All problems in this table are standard constrained optimization problems

Fun	Fun Name	Optimal	Algorithm	Best	Mean	Worst	SD
16	Spring	Not Known	PSO	(+) 0.012858	(+) 0.014863	(+) 0.019145	(+) 0.001262
	Design		ABC	(≈) 0.012665	(+) 0.012851	(+) 0.01321	(+) 0.000118
	Problem		FF	(≈) 0.012665	(+) 0.012931	(+) 0.01342	(+) 0.001454
			SSO-C	(≈) 0.012665	(+) 0.012765	(+) 0.012868	(+) 9.29E-05
			SbPPA	0.012665	0.012666	0.012666	3.39E-10
17	Welded	Not Known	PSO	(+) 1.846408	(+) 2.011146	(+) 2.237389	(+) 0.108513
	Beam		ABC	(+) 1.798173	(+) 2.167358	(+) 2.887044	(+) 0.254266
	Design		FF	(+) 1.724854	(+) 2.197401	(+) 2.931001	(+) 0.195264
	Problem		SSO-C	(≈) 1.724852	(+) 1.746462	(+) 1.799332	(+) 0.02573
			SbPPA	1.724852	1.724852	1.724852	4.06E-08
18	Speed	Not Known	PSO	(+) 3044.453	(+) 3079.262	(+) 3177.515	(+) 26.21731
	Reducer		ABC	(+) 2996.116	(+) 2998.063	(+) 3002.756	(+) 6.354562
	Design		FF	(+) 2996.947	(+) 3000.005	(+) 3005.836	(+) 8.356535
	Optimization		SSO-C	(≈) 2996.113	(≈) 2996.113	(≈) 2996.113	(+) 1.34E-12
			SbPPA	2996.114	2996.114	2996.114	0

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