Differential Evolution Strategies with Random Forest Regression in the Bat Algorithm

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Agenda

- Motivation
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- Background
- Proposed HBARF algorithm
- Experiments and results
- Conclusion

Motivation

- Bat algorithm is a novel method for optimization
- Combine Bat algorithm with DE algorithm
- DE proposes a multitude of strategies
- Predicting the best strategy during the run using various regression methods
- Link computational intelligence with statistical regression methods

Introduction

- Bat algorithm(Yang, 2010) is simple, but very efficient method for optimization
- Hybrid bat algorithm uses a DE strategies for local search
- Random forests create regression on ensemble of DE strategies
- Experiments on suite of five functions taken from literature

Background: Bat algorithm

- Population based algorithm
- Representation of candidate solution(real numbers, binary numbers, quaternions)
- The movement of virtual bats obeys the following equations:

$$Q_i^{(t)} = Q_{min} + (Q_{max} - Q_{min})N(0,1), \tag{1}$$

$$\mathbf{v}_i^{(t+1)} = \mathbf{v}_i^t + (\mathbf{x}_i^t - \mathbf{x}^*)Q_i^{(t)}, \tag{2}$$

$$\mathbf{x}_i^{(t+1)} = \mathbf{x}_i^{(t)} + \mathbf{v}_i^{(t)}. \tag{3}$$

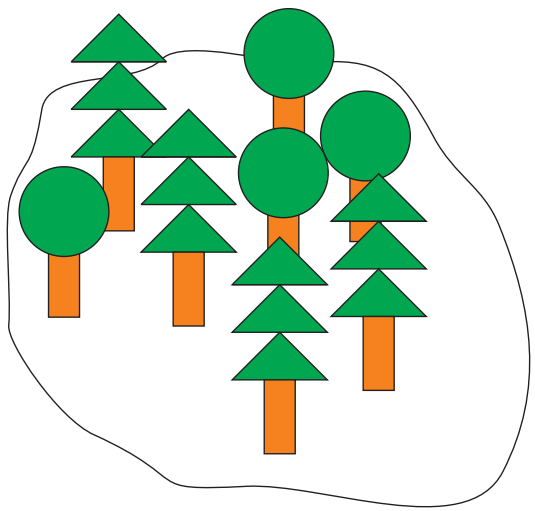
Background: Hybrid bat algorithm

Algorithm 1 Hybrid bat algorithm

1: Objective function $f(x_i)$, $x_i = (x_{i1}, ..., x_{iD})^T$
2: Initialize the bat population x_i and velocities v_i for $i = 1 \ldots NP$
3: Define pulse frequency $Q_i \in [Q_{min}, Q_{max}]$
4: Initialize pulse rates r_i and the loudness A_i
5: while $(t < T_{max})$ // number of iterations
6: Generate new solutions by adjusting frequency, and
7: updating velocities and locations/solutions [Eq. 1 to 3]
8: if$(rand(0,1) > r_i)$
9: Apply DE strategy as a local search
10: end if
11: if$(rand(0,1) < A_i \; and \; f(x_i) < f(x))$
12: Accept the new solutions, Increase r_i and reduce A_i
13: end if
14: Rank the bats and find the current best
15: end while

Background: Random forest

- Developed by Leo Breiman in 2001
- Constructing many decision trees during the training
- Classification and regression



Ensemble of DE strategies

Table: Ensemble of DE-strategies

Nr.	Strategy	Expression
1	Best/1/Exp	$x_{i,j}^{(t+1)} = best_j^{(t)} + F \cdot (x_{r1,j}^{(t)} - x_{r2,j}^{(t)})$
2	Rand/1/Exp	$x_{i,j}^{(t+1)} = x_{r1,j}^{(t)} + F \cdot (x_{r2,j}^{(t)} - x_{r3,j}^{(t)})$
3	RandToBest/1/Exp	$x_{i,j}^{(t+1)} = x_{i,j}^{(t)} + F \cdot (best_i^{(t)} - x_{i,j}^{(t)}) + F \cdot (x_{r1,j}^{(t)} - x_{r2,j}^{(t)})$
4	Best/2/Exp	$x_{i,j}^{(t+1)} = best_i^{(t)} + F \cdot (x_{r1,i}^{(t)} + x_{r2,i}^{(t)} - x_{r3,i}^{(t)} - x_{r4,i}^{(t)})$
5	Rand/2/Exp	$x_{i,j}^{(t+1)} = x_{r1,i}^{(t)} + F \cdot (x_{r2,i}^{(t)} + x_{r3,i}^{(t)} - x_{r4,i}^{(t)} - x_{r5,i}^{(t)})$
6	Best/1/Bin	$x_{j,i}^{(t+1)} = best_i^{(t)} + F \cdot (x_{r1,i}^{(t)} - x_{r2,i}^{(t)})$
7	Rand/1/Bin	$x_{j,i}^{(t+1)} = x_{r1,j}^{(t)} + F \cdot (x_{r2,j}^{(t)} - x_{r3,j}^{(t)})$
8	RandToBest/1/Bin	$x_{j,i}^{(t+1)} = x_{i,j}^{(t)} + F \cdot (best_i^{(t)} - x_{i,j}^{(t)}) + F \cdot (x_{r1,j}^{(t)} - x_{r2,j}^{(t)})$
9	Best/2/Bin	$x_{j,i}^{(t+1)} = best_i^{(t)} + F \cdot (x_{r1,i}^{(t)} + x_{r2,i}^{(t)} - x_{r3,i}^{(t)} - x_{r4,i}^{(t)})$
10	Rand/2/Bin	$x_{j,i}^{(t+1)} = x_{r1,i}^{(t)} + F \cdot (x_{r2,i}^{(t)} + x_{r3,i}^{(t)} - x_{r4,i}^{(t)} - x_{r5,i}^{(t)})$

Modification in Hybrid Bat Algorithm with Random Forest

Algorithm 2 Modification in Hybrid Bat Algorithm with Random Forest

1: if$(rand(0,1) > r_i)$
2: Select the best solution in the current population
3: Generate a test set using the 10 DE-strategies from the best solution
4: Generate a valid set using the candidate solution
5: Apply random forest regression using 10 estimators
6: end if

Experiments

- Goal: how random forest regression method influence the performance of HBA algorithm
- Algorithms in test: BA, HBA, HBARF
- DE parameters:
  - F = 0.5
  - CR = 0.9
- BA parameters:
  - A = 0.5
  - r = 0.5
- RF regression method used 10 estimators

Test suite

Table: Test suite

f	Function	Definition	Range
f_1	Rosenbrock	$F(\mathbf{x}) = \sum_{i=1}^{D-1} 100\,(x_{i+1} - x_i^2)^2 + (x_i - 1)^2$	$-15.00 \leq x_i \leq 15.00$
f_2	Rastrigin	$F(\mathbf{x}) = n * 10 + \sum_{i=1}^{D} (x_i^2 - 10\cos(2\pi x_i))$	$-15.00 \leq x_i \leq 15.00$
f_3	Sphere	$F(\mathbf{x}) = \sum_{i=1}^{D} x_i^2$	$-100.00 \leq x_i \leq 100.00$
f_4	Griewangk	$F(\mathbf{x}) = -\prod_{i=1}^{D} \cos\left(\frac{x_i}{\sqrt{i}}\right) + \sum_{i=1}^{D} \frac{x_i^2}{4000} + 1$	$-600 \leq x_i \leq 600$
f_5	Ackley	$F(\mathbf{x}) = \sum_{i=1}^{D-1} \left(20 + e^{-20} e^{-0.2\sqrt{0.5(x_{i+1}^2 + x_i^2)}} - e^{0.5(\cos(2\pi x_{i+1}) + \cos(2\pi x_i))}\right)$	$-32.00 \leq x_i \leq 32.00$

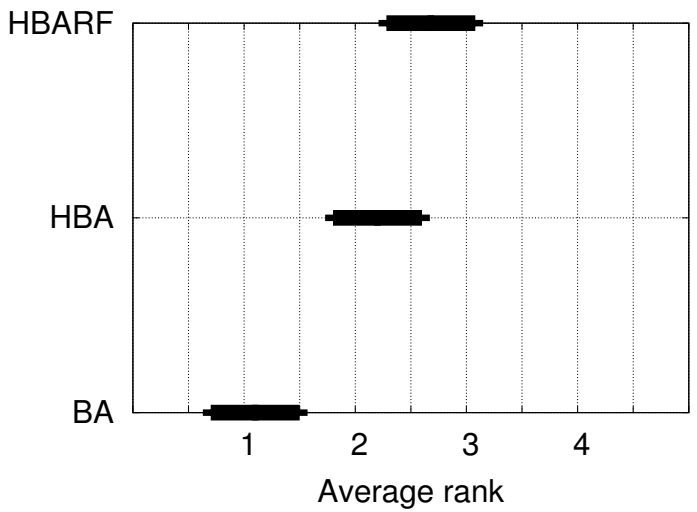
Results

Table: The results of the experiments

Alg.	D	Value	f_1	f_2	f_3	f_4	f_5
BA	10	Best	3.29E+01	1.07E+04	5.33E+01	6.07E+01	1.37E+01
		Worst	1.73E+02	1.58E+06	3.11E+02	5.57E+02	2.00E+01
		Mean	8.30E+01	5.53E+05	1.44E+02	2.27E+02	1.75E+01
		Median	3.91E+01	4.69E+05	6.44E+01	1.06E+02	1.68E+00
		StDev	6.94E+01	4.71E+05	1.48E+02	2.17E+02	1.73E+01
HBA	10	Best	2.25E-09	6.34E-02	**4.83E-09**	5.12E+00	**6.31E-04**
		Worst	**3.97E-05**	5.10E+02	**2.89E-03**	2.38E+01	2.00E+01
		Mean	**3.18E-06**	6.22E+01	**1.26E-04**	1.55E+01	1.16E+01
		Median	8.66E-06	1.15E+02	5.66E-04	4.46E+00	9.26E+00
		StDev	1.14E-07	7.73E+00	**1.66E-07**	1.69E+01	1.78E+01
HBARF	10	Best	**1.44E-11**	**5.00E-05**	2.36E-06	**3.09E-05**	7.21E-04
		Worst	6.35E-04	**1.99E+00**	5.90E-02	**1.02E+01**	**3.53E-01**
		Mean	3.92E-05	**2.64E-01**	5.92E-03	**5.92E-01**	**3.14E-02**
		Median	**1.05E-06**	**1.58E-01**	**4.50E-04**	**1.07E-01**	**1.27E-02**
		StDev	**1.25E-04**	**5.44E-01**	1.22E-02	**2.00E+00**	**6.76E-02**

Friedman tests

Figure: Friedman test



- HBARF improved results of the HBA and BA

Conclusion

- RF might be suitable for swarm intelligence and evolutionary computation
- Regressions might also be very interesting to use in swarm intelligence and evolutionary computation algorithms
- In the future, we would like to test other evolutionary and swarm intelligence algorithms with other regression methods, like extremely randomized trees, decision trees, gradient boosting, etc.