Benchmarking Projection-Based Real Coded Genetic Algorithm on BBOB-2013 Noiseless Function Testbed

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1. Introduction
   - Problem Statement
   - Genetic Algorithms

2. Projection-based Real Coded Genetic Algorithm
   - Projection
   - The PRCGA Algorithm

3. Experimental Procedure
   - Experimental Settings

4. Experimental Results
   - Empirical Results
   - Discussion

5. Thank you
Introduction

Problem Statement

Genetic Algorithms

Projection-based Real Coded Genetic Algorithm

Projection

The PRCGA Algorithm

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Empirical Results

Discussion

Conclusion

Thank you

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Benchmarking PRCGA on BBOB-2013 Noiseless Testbed
The Global Optimization Problem
Real Parameter Optimization

- The task is to minimize an objective function $f$. Given $f : S \rightarrow \mathbb{R}$ where $S \subset \mathbb{R}^n$, find $x^* \in S$ for which,

$$f(x^*) \leq f(x), \quad \forall x \in S.$$  \hfill (1)

- Black Box approach:
  - gradients are not known or not useful.
  - problem domain are rugged and ill-conditioned.

- Goal:
  - To find the global optimum, $x^*$ quickly.
  - With the least search cost (function evaluations).
Genetic Algorithms

- Developed by John Holland in 1975.
- Goal: Develop robust and adaptive systems.
- Solutions are represented internally as genetic encoding of points.
- Reproduction of offspring via:
  - mutation,
  - recombination.
- Selection methods: initially Fitness-proportional method.
- Model: Generational or Steady state.
Real Coded Genetic Algorithms

- Real valued representation are used as genetic encodings of points.
- They are better adapted to numerical optimization of continuous problems.
- They can also be easily hybridized with other search methods.
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Projection

The PRCGA Algorithm

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Experimental Settings

Experimental Results

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Orthogonal Projection of a vector $x$ on a vector $y$

For any two $n$ dimensional vectors, the projection of a vector $x$ on another vector $y$ generates a vector, defined by:

$$
\hat{y} = \frac{x^Ty}{y^Ty}y = \frac{x^Ty}{\|y\|^2}y = \left(\frac{\|x\|\cos(\theta)}{\|y\|}y\right).
$$

(2)

Note that the projected vector $\hat{y}$ (the offspring) will be in the same direction as $y$ unless $\frac{\pi}{2} < \theta < \frac{3\pi}{2}$ in which case the angle, $\theta$, between the two vectors is such that $\cos(\theta) < 0$. As a result, the projected vector is in the opposite direction (the reflection of $y$ about the origin).
Orthogonal Projection of a vector $x$ on a vector $y$

**Figure:** Projection of vector $x$ on vector $y$
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5. Thank you
The PRCGA Algorithm

PRCGA was first introduced as RCGA-P in [6, 7].
- The incorporated projection operator showed promising exploratory search capability in some search problems.
- PRCGA is an enhanced version of RCGA-P.

**Inputs**
- Fitness function $f$.
- Parameters.

**Outputs**
- The Best solution $x_{best}$.
- Fitness value of $x_{best}$, $f(x_{best})$. 
The PRCGA Algorithm

1. Initialize $P_{t=0}$, $P_t = \{x_{1,t}, x_{2,t}, \ldots, x_{N,t}\}$ from $S$
2. $f(x_{i,t}) = \text{evaluate}(P_t), \{1 \leq i \leq N\}$
3. While not stopping condition, do steps 4 - 12
4. $\zeta_t = \sigma(f(P_t))$, if $\zeta_t \leq \epsilon$ do step 5 else step 6
5. $\hat{P}_t = \text{perturb}(P_t)$
6. $\hat{P}_t = \text{tournamentSelection}(P_t)$
7. $C_t = \text{blend-}\alpha\text{Crossover}(\hat{P}_t, p_c)$
8. $M_t = \text{non-uniformMutation}(C_t, p_m)$
9. $\Phi_t = \text{projection}(M_t)$
10. $f(x_{i,t}) = \text{evaluate}(\Phi_t)$
11. $P_{t+1} = \text{replace}(P_t, \Phi_t)$
12. $t = t + 1$
13. end while
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   - Empirical Results
   - Discussion

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Computer System and Software

**Computer System Configuration**
- HP Probook 6545b with AMD Turion(tm) II Ultra Dual-Core mobile M620 CPU processor.
- CPU Speed: 2.5GHz.
- RAM: 2.75GB

**Software**
- Microsoft Windows 7 Professional service pack 1.
- MATLAB 7.10 (R2010a).
- COmparing Continuous Optimisers (COCO) software.
- Post-Processing Script in Python
The experimental setup was carried out according to [3] on the benchmark functions provided in [2, 4].

Two independent restart strategies were employed

- Checks for stagnation [1].
- Maximum number of generations reached without $f_{\text{target}}$.

For each restart strategy, the genetic run is initiated with an initial population $P_0$ which is $\sim \text{Unif}([-4, 4]^D)$. 
Parameter Settings

Parameters

- Population Size = \( \min(100, 100 \times D) \), where \( D \) = dimension.
- Maximum Number of Evaluation = \( 10^5 \times D \).
- Tournament size = 3.
- Crossover rate \( p_c = 0.8 \).
- Mutation rate \( p_m = 0.15 \).
- Non-uniformity factor for Mutation \( \beta = 15 \).
- Crafting effort \( CrE = 0 \).
The CPU timing experiment was conducted using the same independent restart strategies on the function $f_8$ for a duration of 30 seconds.

| Dimension | 2  | 3  | 5  | 10 | 20 | 40 |
|-----------|----|----|----|----|----|--|---|
| Time ($\times 10^{-5}$) | 7.1 | 7.5 | 6.9 | 6.9 | 7.1 | 8.0 |
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Ellipsoid separable

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Rastrigin separable

Benchmarking PRCGA on BBOB-2013 Noiseless Testbed
Skew Rastrigin-Bueche separable

Benchmarking PRCGA on BBOB-2013 Noiseless Testbed
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Separable Functions

- PRCGA performed well on separable functions $f_1 - f_4$.
- PRCGA also solved Gallagher’s Gaussian 101-me Peaks Function $f_{21}$, a multi-modal function with weak global structure.
- PRCGA showed some encouraging performance in solving problems $f_6 - f_7$ in dimensions 2 – 10.

Functions with high conditioning and unimodal

- Functions $f_{10} - f_{14}$ prove to be difficult for PRCGA to solve to the required level of accuracy.
Comparison of PRCGA with Previous GAs

- DBRCGA [1] outperformed PRCGA.
- PRCGA performed better than the RCGA in [8].
- PRCGA performed better than the simpleGA in [5].
The benchmarking of PRCGA on noiseless BBOB function testbed shows the strengths and weaknesses of the algorithm.

The performance of PRCGA shows that in its current form it cannot compete with state-of-the-art evolutionary algorithms.
Thank You!!!
For Further Reading


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