

Tracking the exploration and exploitation in stochastic population-based nature-inspired algorithms using recurrence plots

Daniel Angus and Iztok Fister Jr.
E: iztok.fister1@um.si

Agenda

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Goals of this study

The main contributions of this study are summarized as follows:

- to verify that there is a possibility to track the whole path of a stochastic population-based nature-inspired algorithm during the evolutionary process using recurrence plots and
- to investigate whether there is a possibility to observe changes between the exploration phase as well as the exploitation phase on recurrence plots,
- to study if there is a possibility to decide which algorithm is good for a particular problem based on the visualization of recurrence plots.

Recurrence plotting

- The recurrence plotting technique was initially invented as a technique to display and identify patterns from time series data.
- The recurrence plot is a 2D plot where the horizontal and vertical axes represent time series data, and individual elements of the plot indicate times where the phase space trajectory of the system visits the same region of phase space.

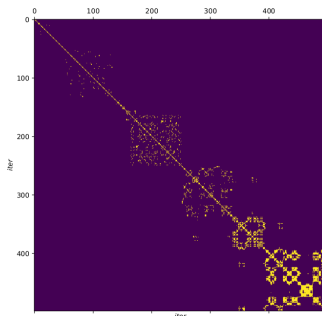


Figure: An example of recurrence plot.

Recurrence quantification analysis

- Recurrence Quantification Analysis (RQA) extends this technique by specifying a set of metrics designed to capture specific features of recurrence plots.
- RQA has been applied across diverse areas including financial analysis, neural recordings, engineering.
- Many RQA measures: recurrence rate, laminarity, trapping time

Our approach

- We conducted a series of experiments on 4 benchmark functions.
- Four algorithms were included in experiments (BA, FA, PSO, DE).
- Population similarity is based on Euclidean distance.

f	Function name	Definition
$f1$	Sphere	$f(x) = \sum_{i=1}^D x_i^2$
$f2$	Ackley	$f(x) = -a \exp \left(-b \sqrt{\frac{1}{D} \sum_{i=1}^D x_i^2} \right) - \exp \left(\frac{1}{D} \sum_{i=1}^D \cos(c x_i) \right) + a + \exp(1)$
$f3$	Griewank	$f(x) = \sum_{i=1}^D \frac{x_i^2}{4000} - \prod_{i=1}^D \cos\left(\frac{x_i}{\sqrt{i}}\right) + 1$
$f4$	Rastrigin	$f(x) = 10D + \sum_{i=1}^D (x_i^2 - 10 \cos(2\pi x_i))$

Table: Benchmark functions used in our experiments.

Population similarity score calculation

```
1: Score = 0
2: for  $i = 1$  to  $NP_{P1}$  do
3:   for  $j = 1$  to  $NP_{P2}$  do
4:     Score+ = Score( $P1_i, P2_j$ )
5:   end for
6: end for
7: Score/ =  $NP$ 
```

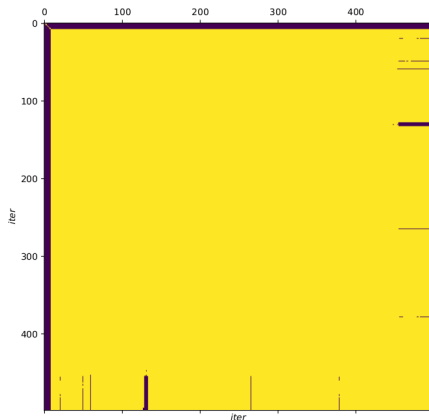
```
1: TimeSeries =  $\emptyset$ ;
2: for  $i = 1$  to  $MAX\_ITER$  do
3:   Point = Calculate_population_similarity()
4:   TimeSeries.append(Point)
5: end for
6: TimeSeries = normalize(TimeSeries(0, 1))
```

RQA analysis and generating a recurrence plot

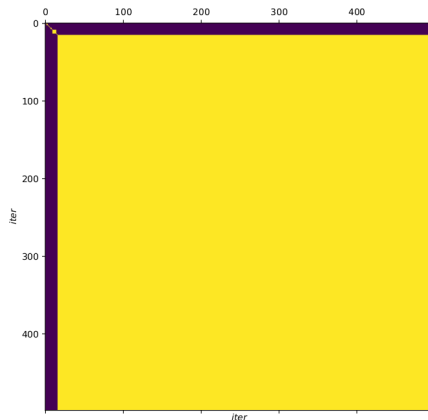
- Each population-based nature-inspired algorithm was run for 500 iterations:
 - ▶ generating 20 new solutions per generations.
- 25 independent runs.
- Dimension of the problem was set to 30.

For generating a recurrence plot, we chose 1 single run randomly from the pool of 25 runs.

Results BA



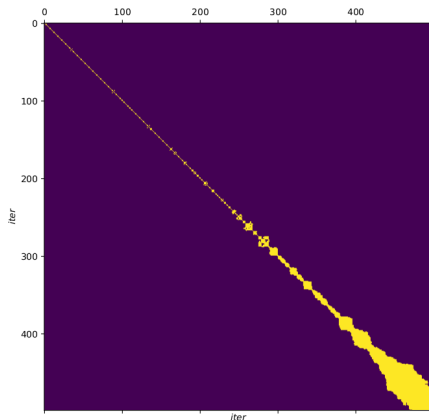
(a) Ackley



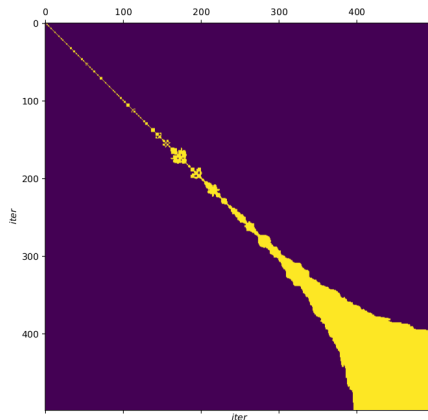
(b) Griewank

Figure: Recurrence plots of BA on selected benchmark functions

Results FA



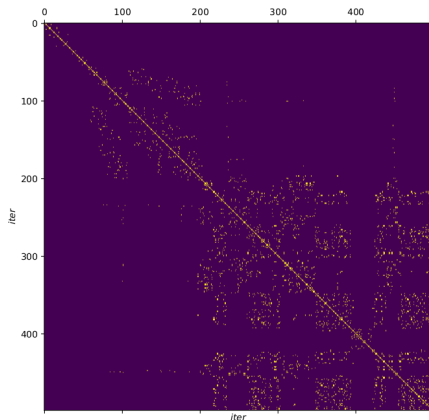
(a) Ackley



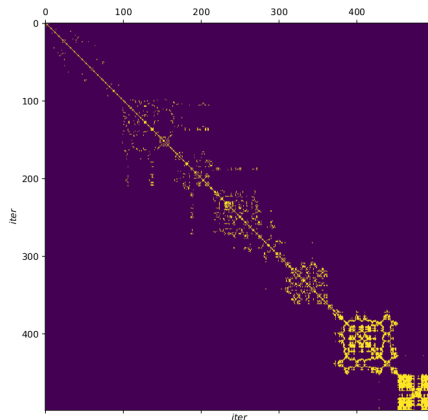
(b) Sphere

Figure: Recurrence plots of FA on selected benchmark functions

Results PSO



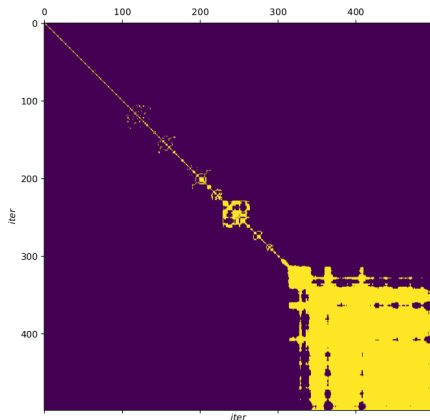
(a) Rastrigin



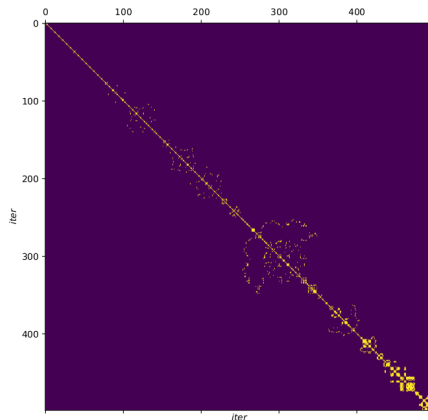
(b) Sphere

Figure: Recurrence plots of PSO on selected benchmark functions

Results DE



(a) Ackley



(b) Griewank

Figure: Recurrence plots of DE

Conclusions

- We applied a well-known visualization technique, recurrence plotting for tracking the exploitation of stochastic population-based nature-inspired algorithms.
- Recurrence plotting is efficient way of visualizing the trajectory of stochastic population-based nature-inspired algorithms.
- In the future more complex problems and more algorithms should be taken into account.
- Future work could also examine the impact of different population similarity measurements on the resulting recurrence plots.