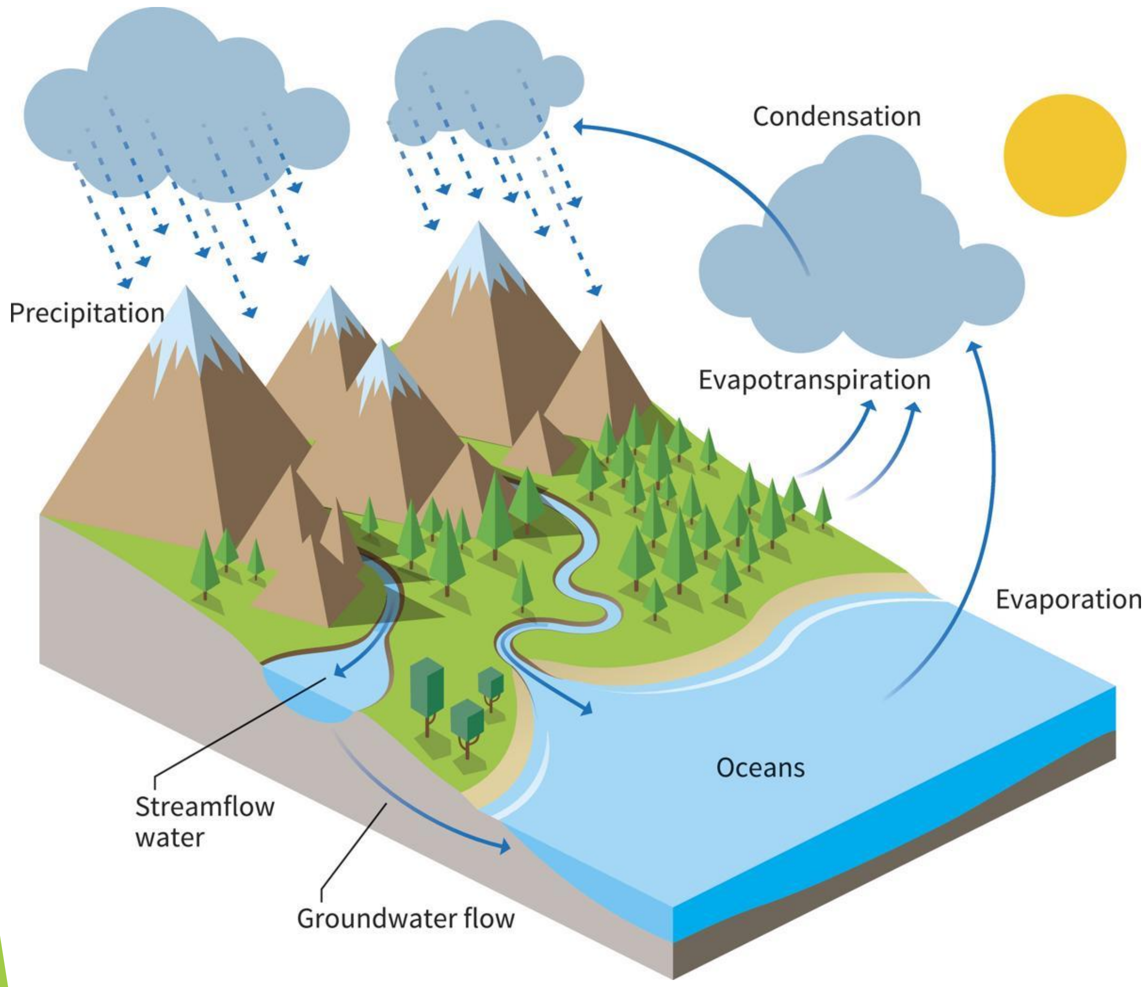
Water Cycle Algorithm

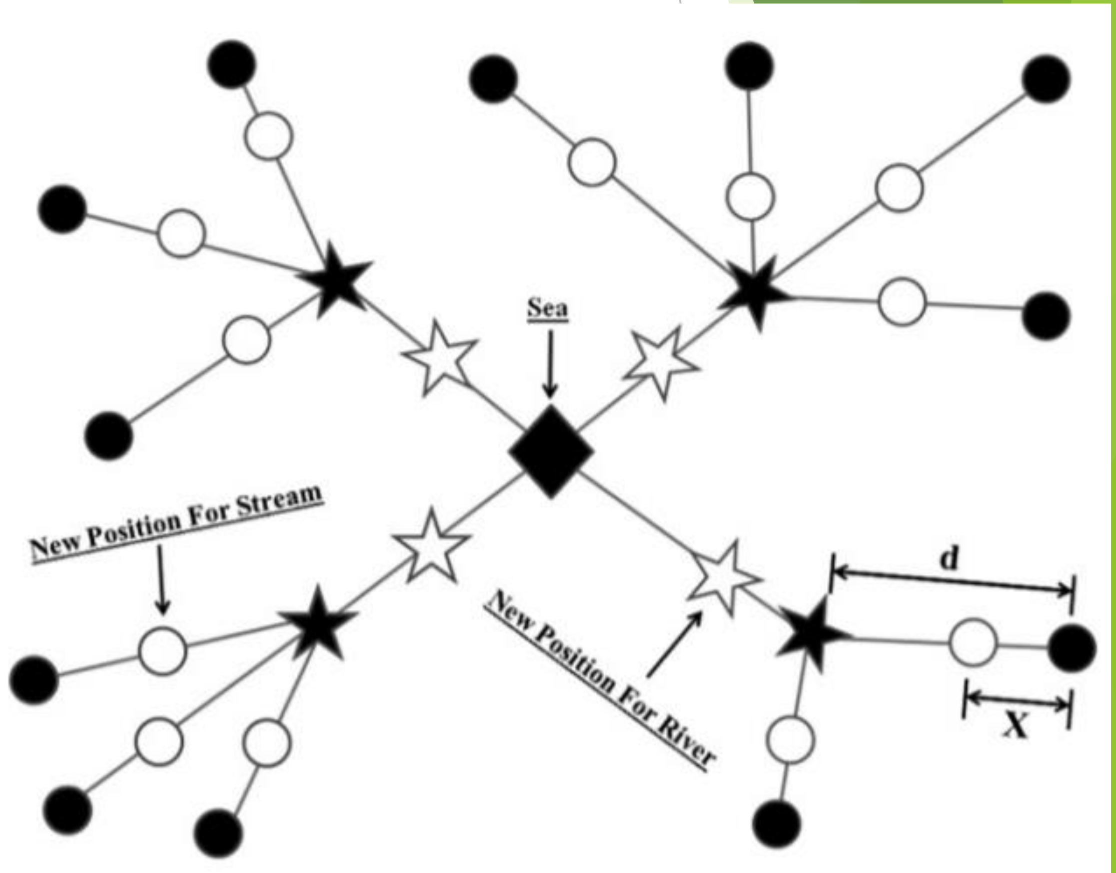
R08546026 紀淳展

Outline

- Introduction
- Algorithm
- Demo
- Testing and Comparison
- Conclusion and Discussion
- References

Water Cycle


Condensation
Precipitation
Evapotranspiration
Evaporation
Oceans
Streamflow water
Groundwater flow


Sea
New Position For Stream
New Position For River
d
X

Algorithm

Choose initial parameters($N_{pop}, N_{sr}, d_{max}, Iteration\_Limit$);

Generate random initial population(streams, rivers, sea);

Calculate the cost of each raindrops, and Determine the intensity of flow;

do

  Streams flow to rivers;

  Rivers flow to sea;

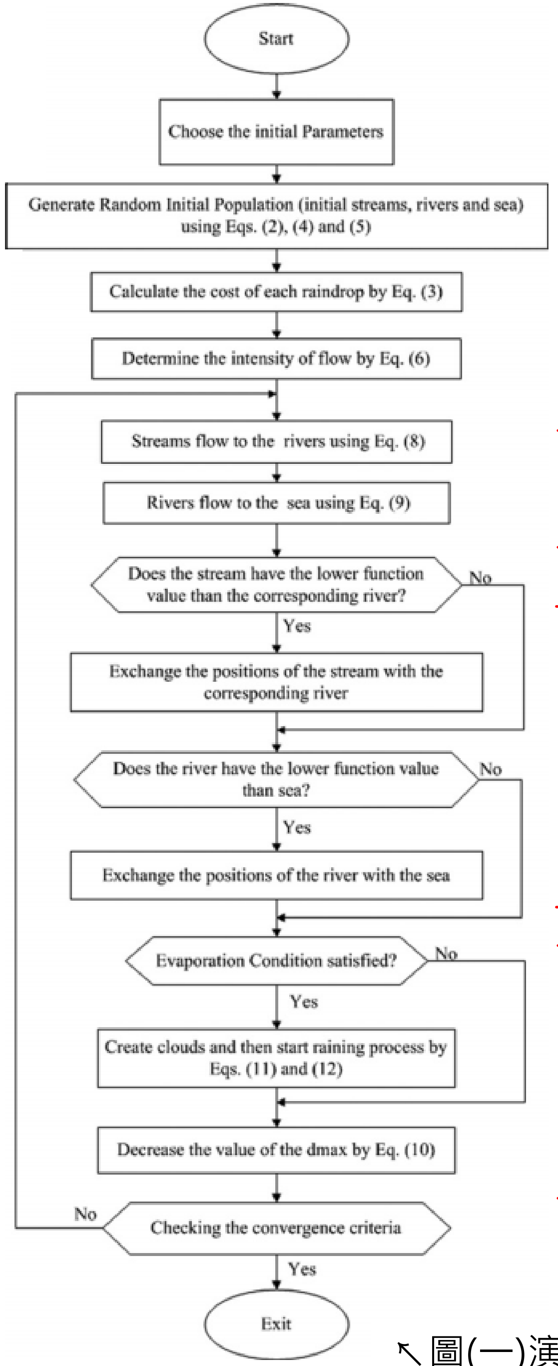
  if(cost(stream) > cost(river)) { exchange };

  if(cost(river) > cost(sea)) { exchange };

  If(| $X_{river} - X_{sea}$ | < d_{max}) { $X_{stream}^{new} = LB + rand \times (UB - LB)$ }

  $$d_{max} = d_{max} - \frac{d_{max}}{iteration\_limit}$$

while{ iteration count < iteration limit };



↖圖(一)演算法流程圖

1.初始化

$(N_{pop}, N_{sr}, d_{max}, Iteration\_Limit)$

$$\text{Population of raindrops} = \begin{bmatrix} \text{Raindrop}_1 \\ \text{Raindrop}_2 \\ \text{Raindrop}_3 \\ \vdots \\ \text{Raindrop}_{N_{pop}} \end{bmatrix} = \begin{bmatrix} x_1^1 & x_2^1 & x_3^1 & \cdots & x_{N_{var}}^1 \\ x_1^2 & x_2^2 & x_3^2 & \cdots & x_{N_{var}}^2 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ x_1^{N_{pop}} & x_2^{N_{pop}} & x_3^{N_{pop}} & \cdots & x_{N_{var}}^{N_{pop}} \end{bmatrix}$$

$$N_{sr} = \text{Number of Rivers} + \underbrace{1}_{\text{Sea}}$$

$$N_{\text{Raindrops}} = N_{pop} - N_{sr}$$

$$C_i = \text{Cost}_i = f(x_1^i, x_2^i, \ldots, x_{N_{var}}^i) \quad i = 1, 2, 3, \ldots, N_{pop}$$

$$NS_n = \text{round}\left\{\left|\frac{\text{Cost}_n}{\sum_{i=1}^{N_{sr}} \text{Cost}_i}\right| \times N_{\text{Raindrops}}\right\}, \quad n = 1, 2, \ldots, N_{sr} \qquad (6)$$

2.解的移動過程

$$X_{\text{Stream}}^{i+1} = X_{\text{Stream}}^{i} + rand \times C \times \left(X_{\text{River}}^{i} - X_{\text{Stream}}^{i}\right) \qquad (8)$$

$$X_{\text{River}}^{i+1} = X_{\text{River}}^{i} + rand \times C \times \left(X_{\text{Sea}}^{i} - X_{\text{River}}^{i}\right) \qquad (9)$$

3.判斷最佳解和次佳解是否需要更新

4. 蒸發作用

$$\text{if } \left|X_{\text{Sea}}^{i} - X_{\text{River}}^{i}\right| < d_{\max} \quad i = 1, 2, 3, \ldots, N_{sr} - 1$$

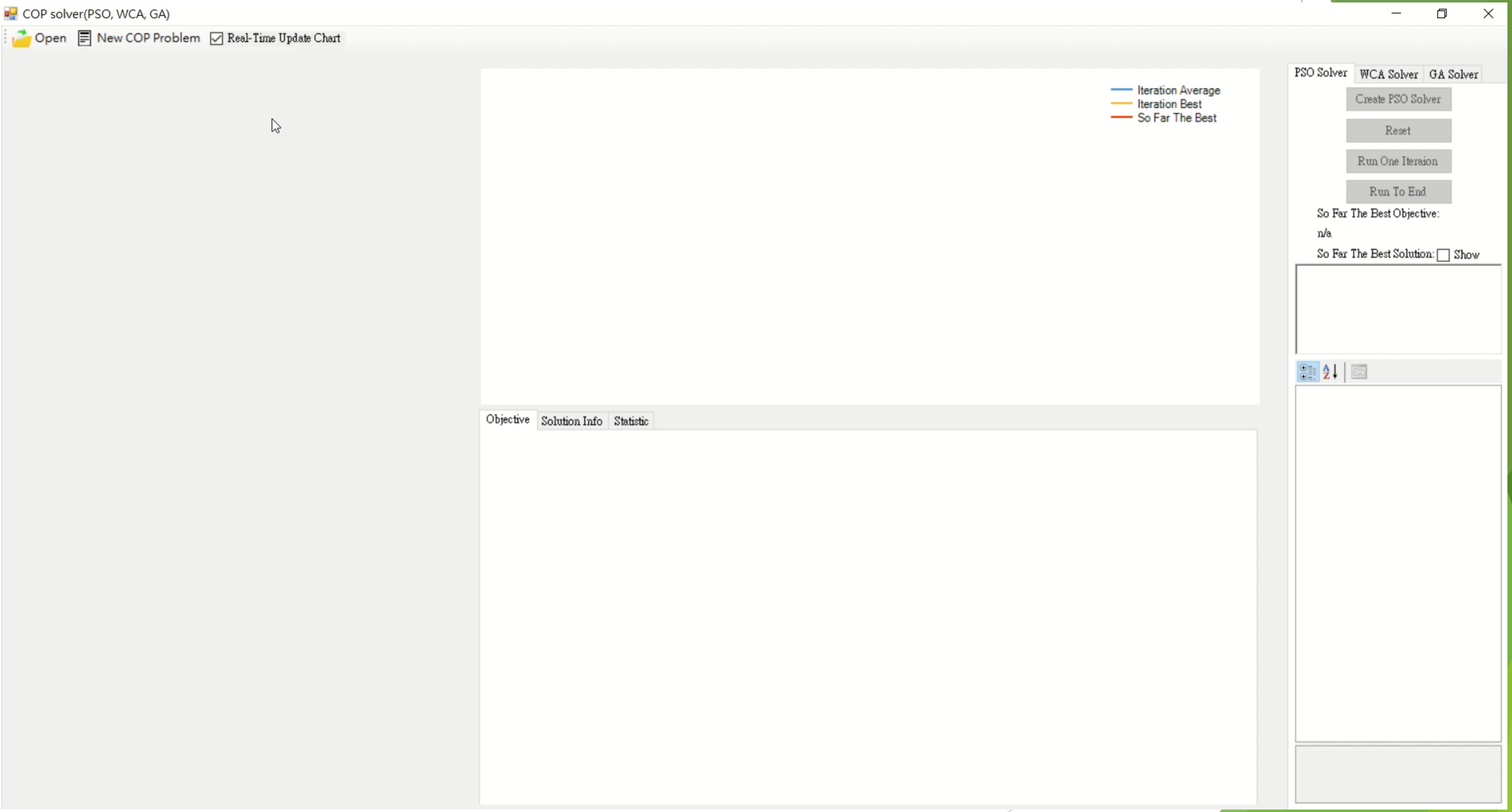
Evaporation and raining process

end

$$X_{\text{Stream}}^{\text{new}} = LB + rand \times (UB - LB) \qquad (11)$$

$$d_{\max}^{i+1} = d_{\max}^{i} - \frac{d_{\max}^{i}}{\text{max iteration}} \qquad (10)$$

Demo

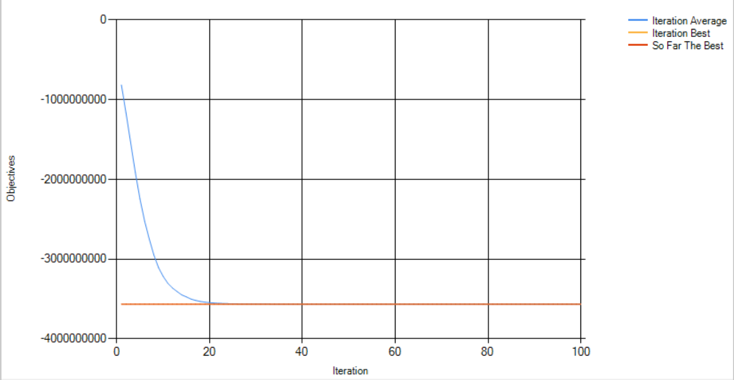
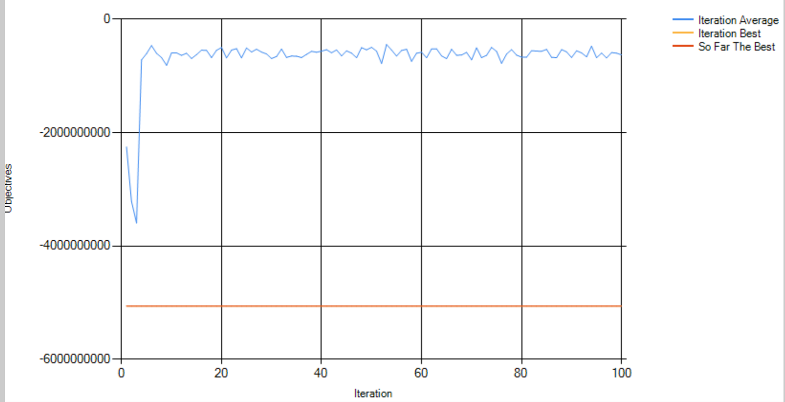
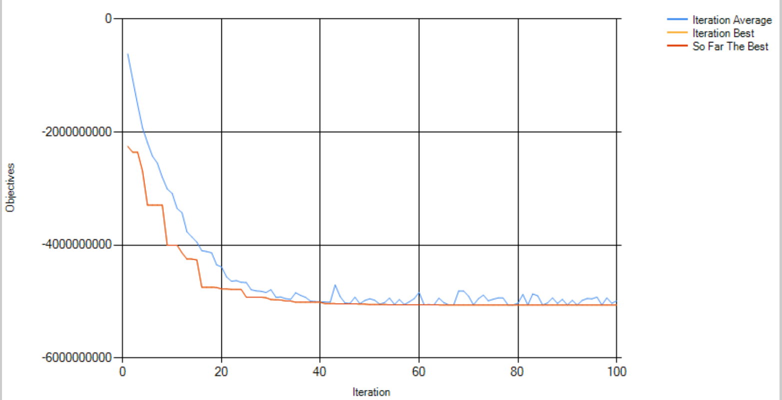


COP solver(PSO, WCA, GA)
Open
New COP Problem
Real-Time Update Chart
Iteration Average
Iteration Best
So Far The Best
Objective
Solution Info
Statistic
PSO Solver
WCA Solver
GA Solver
Create PSO Solver
Reset
Run One Iteraion
Run To End
So Far The Best Objective:
n/a
So Far The Best Solution:
Show

Testing

- 1. Pressure vessel design problem

$$
\begin{aligned}
&\min\ f(\mathbf{x}) = 0.6224\,x_1x_3x_4 + 1.7781\,x_2x_3^2 + 3.1661\,x_1^2x_4 + 19.84\,x_1^2x_3 \\
&s.t. \\
&g_1(\mathbf{x}) = -x_1 + 0.0193\,x_3 \le 0 \\
&g_2(\mathbf{x}) = -x_2 + 0.00954\,x_3 \le 0 \\
&g_3(\mathbf{x}) = -\pi x_3^2 x_4^2 - \tfrac{4}{3}\pi x_3^3 + 1296000 \le 0 \\
&g_4(\mathbf{x}) = x_4 - 240 \le 0 \\
&1 \times 0.0625 \le x_1, x_2 \le 99 \times 0.0625 \\
&10.0 \le x_3, x_4 \le 200.0
\end{aligned}
$$

	PSO	WCA	GA
			
best	-4481676527.99385	-5058756582.51544	-5058755061.1774
mean	-3902356542.15486	-5058756582.51544	-5058723226.49379
sd	442885881.370585	110.851251684408	40078.2083431882

Comparison

- 2. Ackley(2)

Bound:

$$-32.768 \le x_i \le 32.768, i = 1, 2, \ldots, D$$

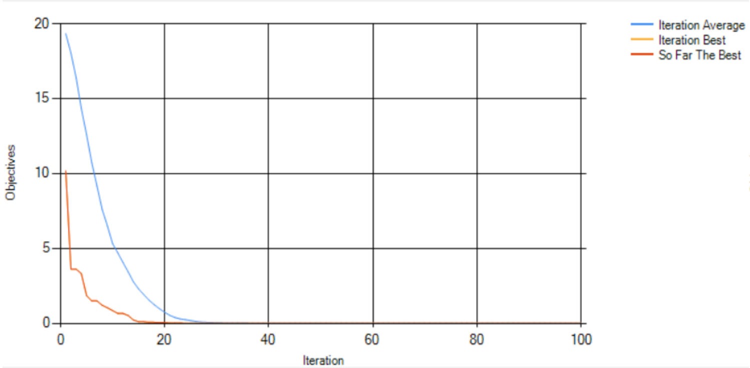
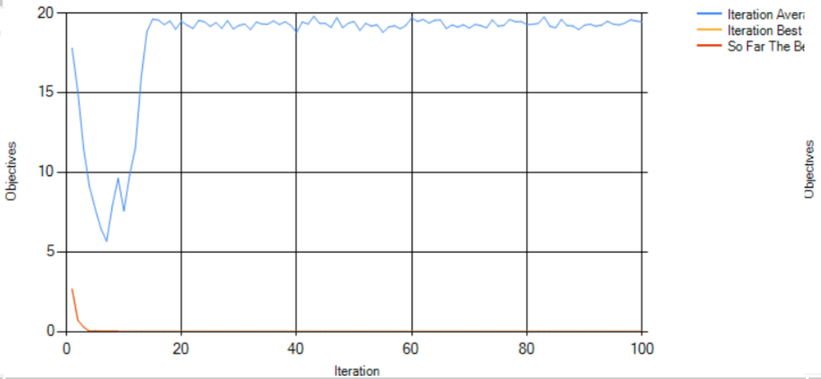
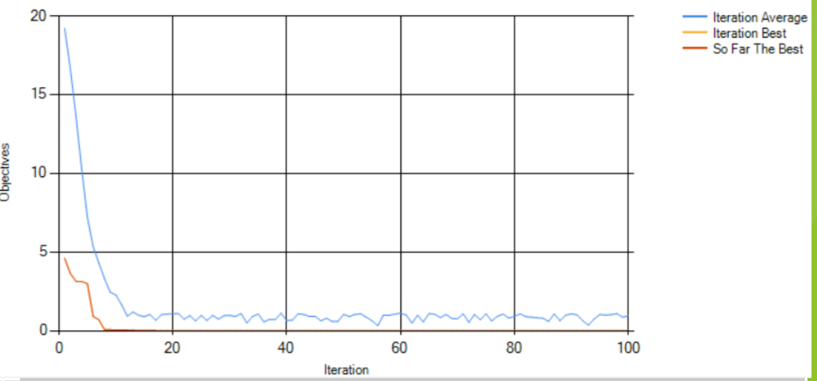
Problem:

$$\min \; 20 + e - 20e^{\left(-0.2\sqrt{\frac{1}{D}\sum_{i=1}^{D} x_i^2}\right)} - e^{\frac{1}{D}\sum_{i=1}^{D}\cos(2\pi x_i)}$$

Optimal Value: 0

Optimal Solution(s):

$$(x_i) = (0), i = 1, 2, \ldots, D$$

	PSO	WCA	GA
			
best	1.13287157432751E-12	1.09350703292321E-06	2.18418660935527E-09
mean	1.9290347097467E-12	0.000283744231234495	0.0154450336571208
sd	3.80172484450748E-12	0.000386171098829325	0.0407555463728095

Comparison

- 3. Ackley(30)

Bound:

$$-32.768 \le x_i \le 32.768, i = 1, 2, \ldots, D$$

Problem:

$$\min \; 20 + e - 20e^{\left(-0.2\sqrt{\frac{1}{D}\sum_{i=1}^{D} x_i^2}\right)} - e^{\frac{1}{D}\sum_{i=1}^{D}\cos(2\pi x_i)}$$

Optimal Value: 0

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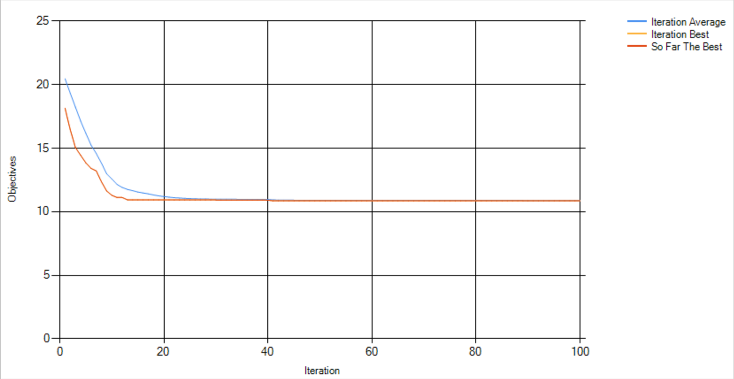
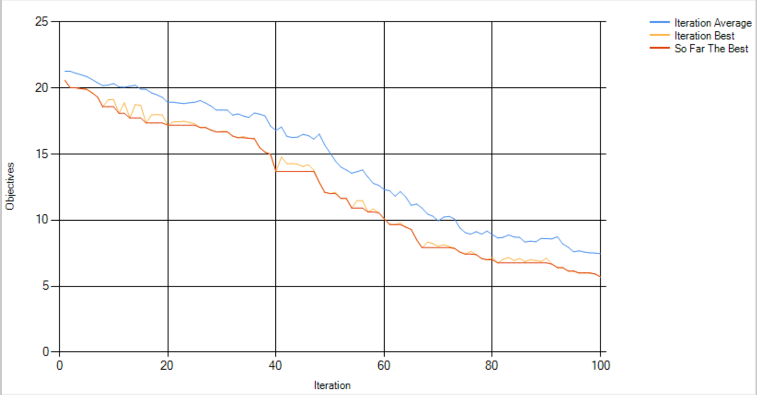
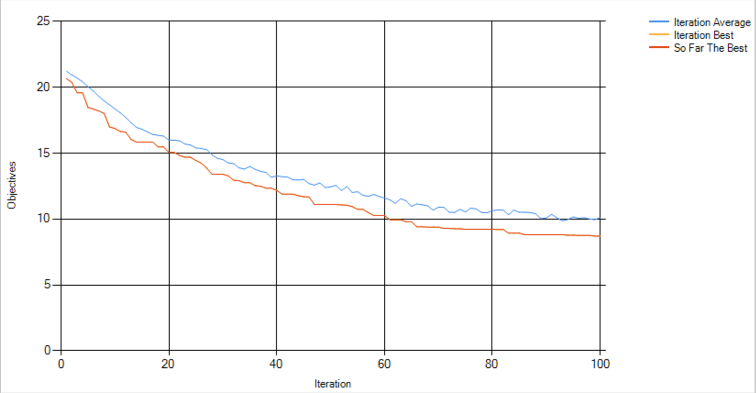
	PSO	WCA	GA
			
best	9.41136986405277	1.6528470322865	6.46509038334138
mean	10.6643271369808	12.7354740108699	8.08330306653138
sd	0.836986096259919	7.12072807299009	0.785300755981841

Conclusion and Discussion

- 優點：
  - 1.使用者參數少，容易調整和理解
  - 2.高維度的問題中，在有限次數有辦法找到較好的最佳解
- 缺點：
  - 普遍的表現沒有特別比PSO和GA好
- 如何改進？
  - 針對下雨的地點設計
  - 蒸發條件修改或增加

References

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- Ali Sadollaha , Hadi Eskandarb , Ho Min Leea , Do Guen Yooa , Joong Hoon Kim(2016). Water cycle algorithm: A detailed standard code
- Kong Yanjun, Mei Yadong, Li Weinan, Wang Xianxun, Ben Yue(2017). An enhanced water cycle algorithm for optimization of multi-reservoir systems