The LifeCycle model: Combining Particle Swarm Optimisation, Genetic Algorithms and HillClimbers

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Life Cycle Concept

- Animals in nature progress through stages
- Change their actions and life based on stimuli/time
- This can be adapted to modify optimization algorithms

Models - PSO Model

- Particles move around a search space
- Record the best location found by all the particles
  - Modify velocity based on the best point found

$$\boldsymbol{v}_i = \chi(w\boldsymbol{v}_i + \boldsymbol{\varphi}_{1i}(\boldsymbol{p}_i - \boldsymbol{x}_i) + \boldsymbol{\varphi}_{2i}(\boldsymbol{p}_g - \boldsymbol{x}_i))$$

- Over time, the particles converge on an overall best value

Models - GA Model

- Standard genetic algorithm
- Each individual represents a solution
  - Mutations are done on each individual to modify their position
  - A new generation is made from the mutated individuals

$$\boldsymbol{x}_{child1} = w * \boldsymbol{x}_{parent1} + (1 - w) * \boldsymbol{x}_{parent2}$$
$$\boldsymbol{x}_{child2} = w * \boldsymbol{x}_{parent2} + (1 - w) * \boldsymbol{x}_{parent1}$$

$$\Delta x_j = \begin{cases} +(Max - x_j)(1 - r^{(1-t/T)^b}) \\ -(x_j - Min)(1 - r^{(1-t/T)^b}) \end{cases}$$

- Binary tournament selection to perform culling
  - Elitism to not perform culling

Models - HillClimber

- Individuals represent a given solution
  - Look at the surrounding values
  - Choose a random nearby value, weighted by its fitness

$$p = 1/(1 + exp(\frac{eval(\boldsymbol{x}_n) - eval(\boldsymbol{x}_c)}{T})) \qquad (minimisation)$$

- Effective at finding local optima

Models - LifeCycle

- Combination of all previous models

- Mimics life cycle process in nature
  - Designed to switch when the fitness is not changing quickly enough (50 iterations)
  - PSO > GA > HillClimb > PSO > etc.

```
program LifeCycle_Model
begin
    initialise
    while (not terminate-condition) do
        begin
            for (all individuals)
                evaluate fitness
                switch LifeCycle stage if no recent improvement
            for (PSO particles)
                calculate new velocity vectors
                move
            for (GA individuals)
                select new population
                recombine population
                mutate population
            for (HillClimbers)
                find possible new neighbouring solution
                evaluate fitness for the new solution
                shift to new solution with probability p
        end
end
```

Fig. 1. Structure of the LifeCycle model.

Experimental Settings

Compare the performance of standard PSO, GA, HillClimber and LifeCycle

5 numerical minimisation problems are used for testing

Table 1. Test functions

Sphere	$f_1(x) = \sum_{i=1}^{n} x_i^2$
Rosenbrock	$f_2(x) = \sum_{i=1}^{n-1} (100(x_{i+1} - x_i^2)^2 + (x_i - 1)^2)$
Griewank	$f_3(x) = \frac{1}{4000} \sum_{i=1}^{n} (x_i - 100)^2 - \prod_{i=1}^{n} cos(\frac{x_i - 100}{\sqrt{i}}) + 1$
Rastrigin	$f_4(x) = \sum_{i=1}^{n} (x_i^2 - 10cos(2\pi x_i) + 10)$
Ackley	$f_5(x) = 20 + e - 20e^{-0.2\sqrt{\frac{1}{n}\sum_{i=1}^{n} x_i^2}} - e^{\frac{1}{n}\sum_{i=1}^{n} cos(2\pi x_i)}$

Experiment Result

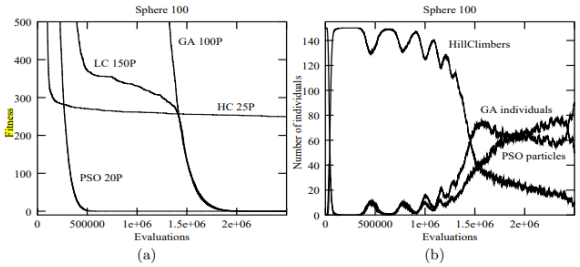

Fig. 2. Sphere function: (a) Performance of the standard GA with population size 100, the standard PSO with population size 20, 25 HillClimbers and the LifeCycle model with population size 150. (b) Composition of LifeCycle individuals.

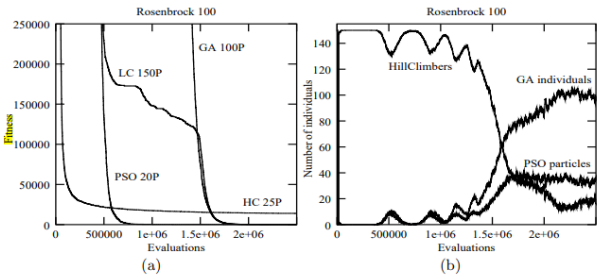

Fig. 3. Rosenbrock function: (a) Performance. (b) Composition of LifeCycle individuals three. Moreover, we set the mutation loop dependency b to 5 and used a fixed population size of 100 individuals.

HC fails to find a exact solution while it has the fastest improvement.

LC is faster than normal GA but lower than PSO

Experiment Result

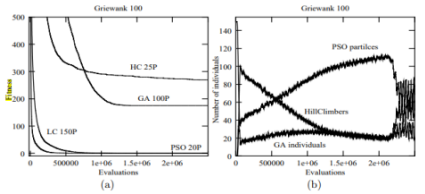

Fig. 4. Griewank function: (a) Performance. (b) Composition of LifeCycle individuals.

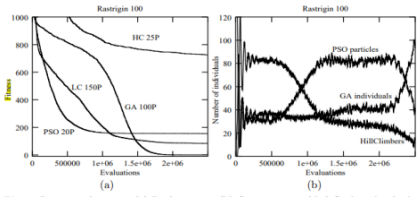

Fig. 5. Rastrigin function: (a) Performance. (b) Composition of LifeCycle individuals.

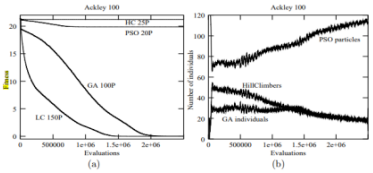

Fig. 6. Ackley function: (a) Performance. (b) Composition of LifeCycle individuals.

PSO is better than GA in Griewank, Rastrigin

LC can always keep a relatively fast speed, and it is also the fastest in Ackley (Reliable, Steady)

Questions?