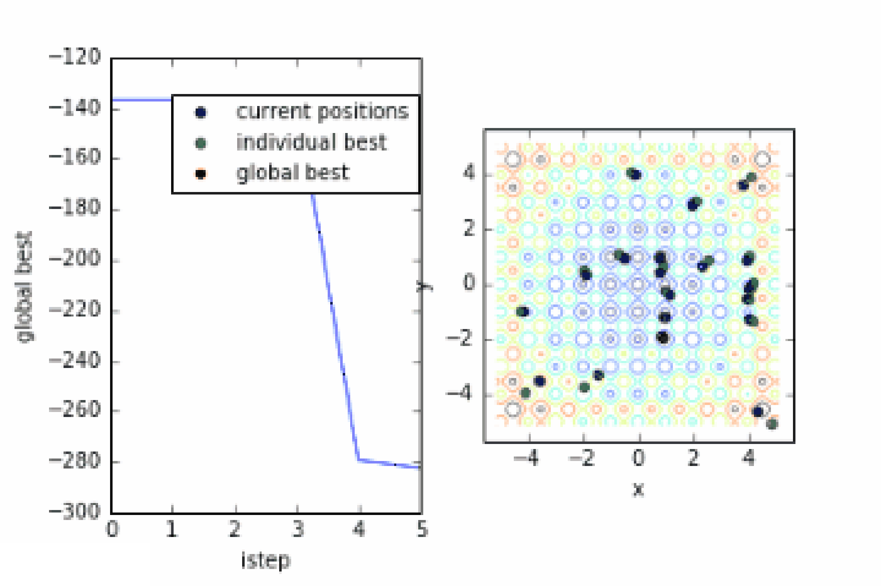
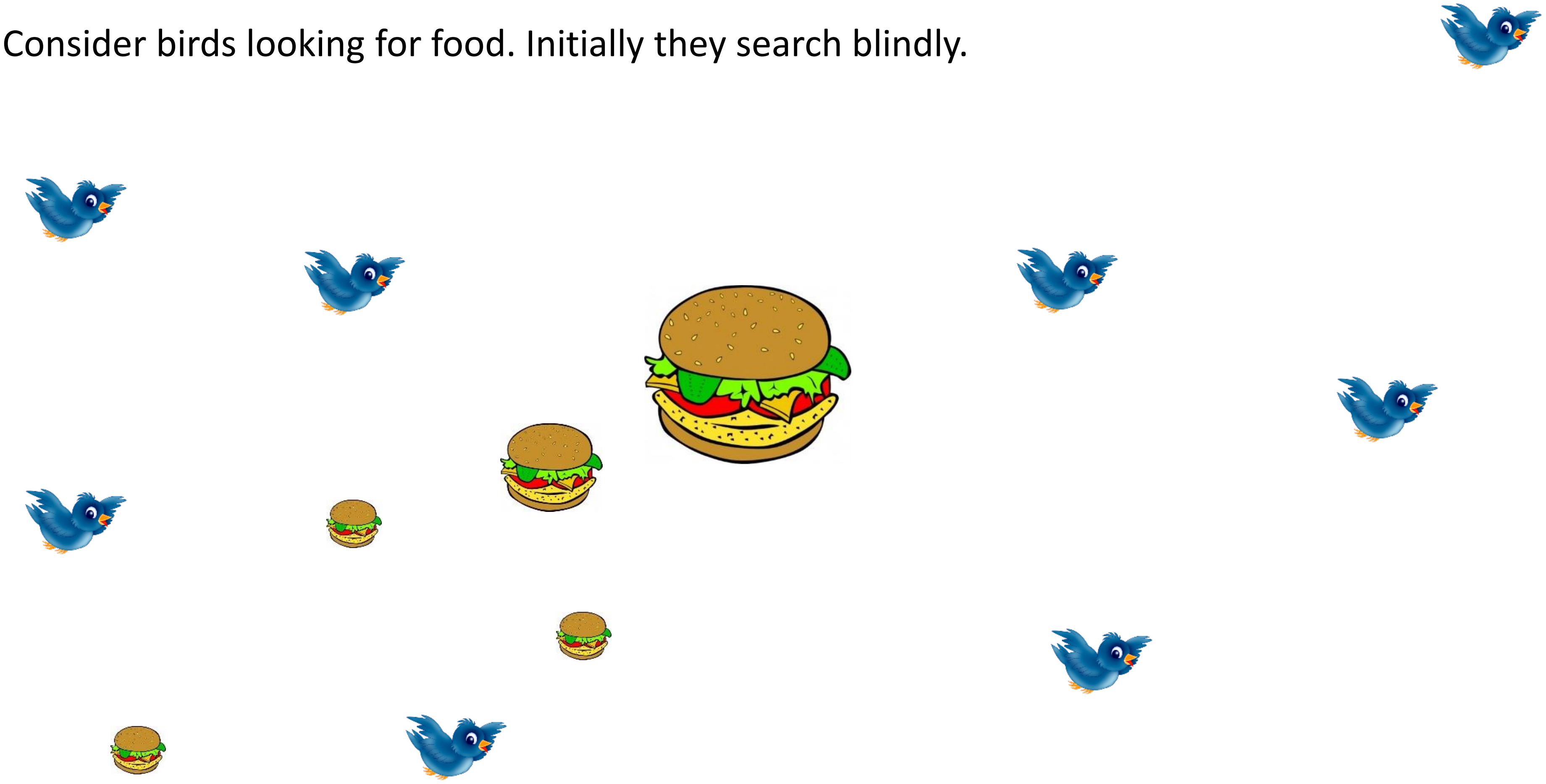
Particle Swarm Optimization

Presented by: Yubo “Paul” Yang



Motivation: Swarm Intelligence

Consider birds looking for food. Initially they search blindly.



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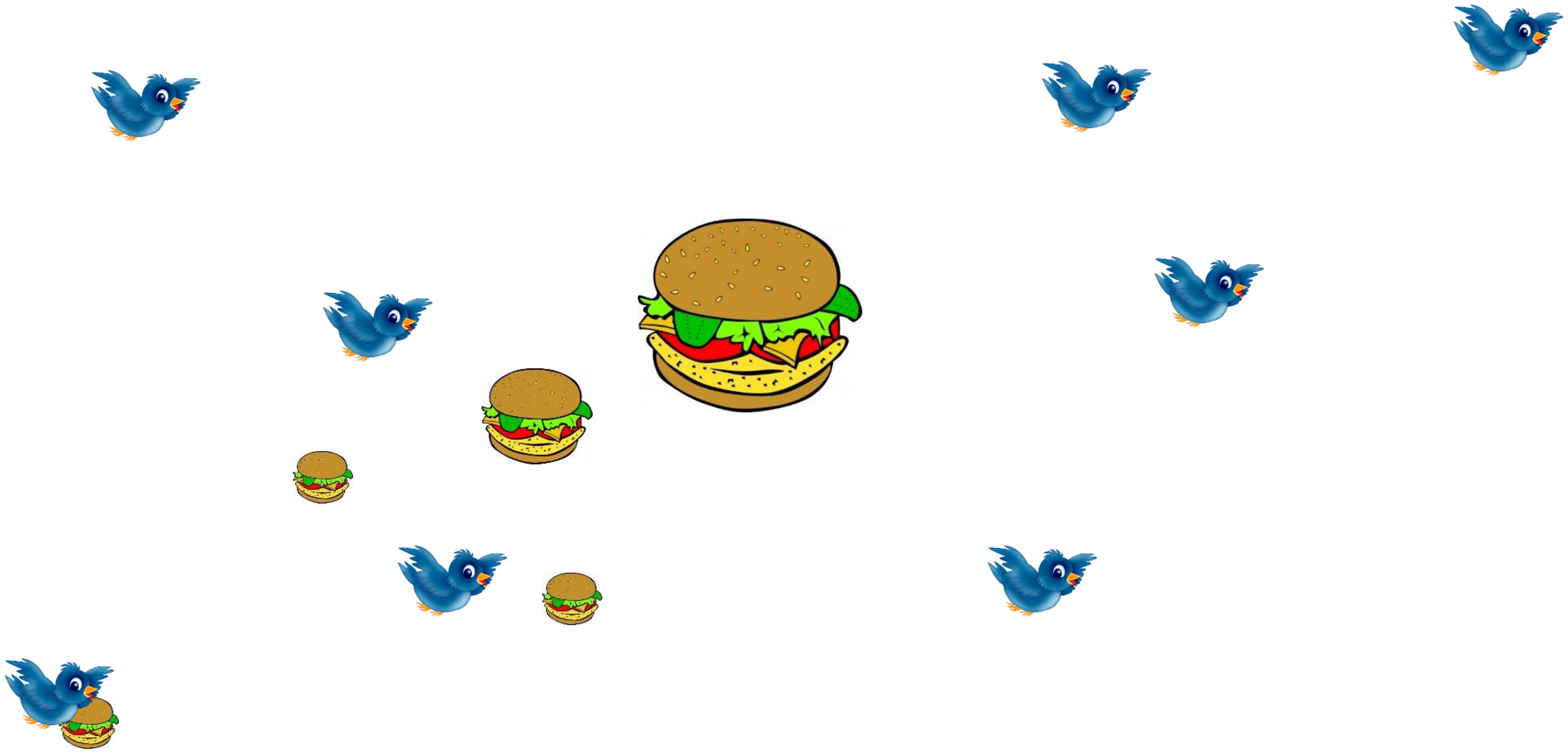
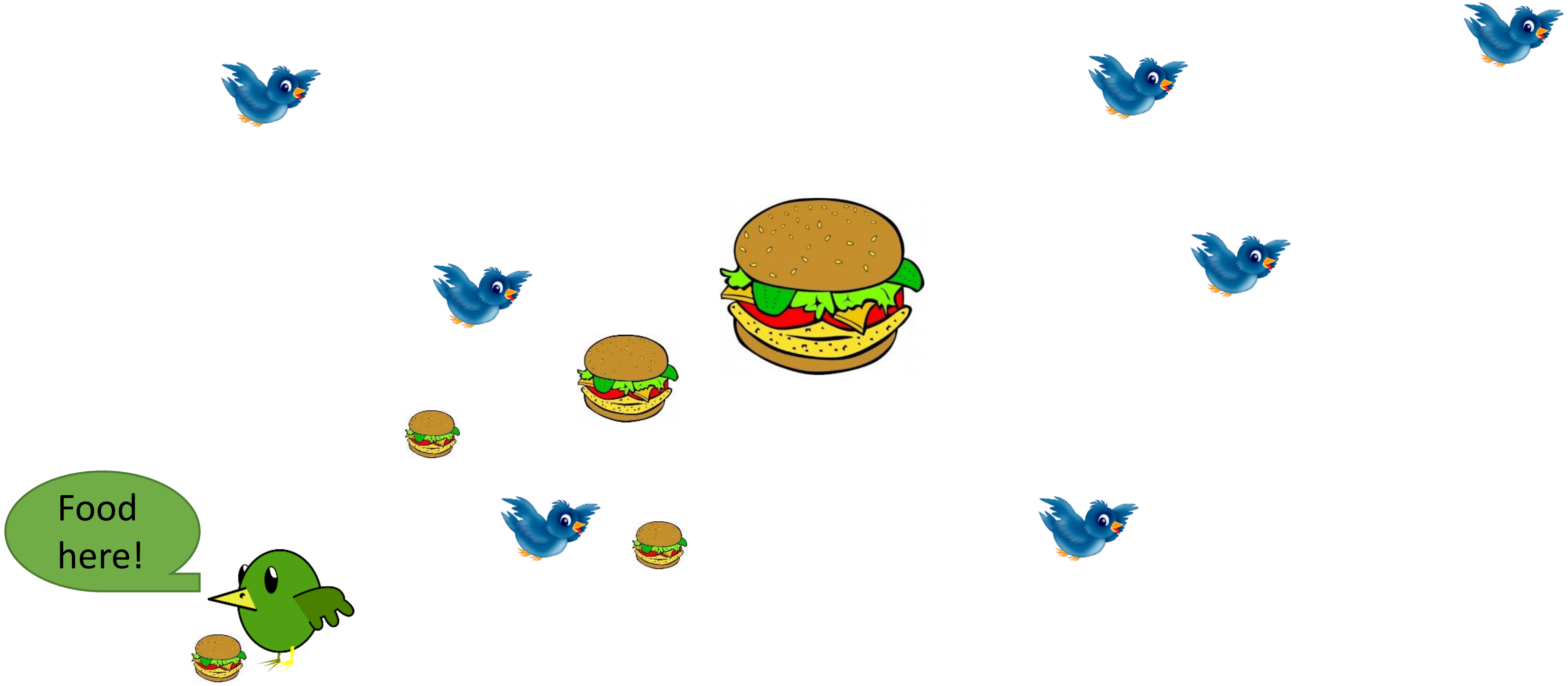


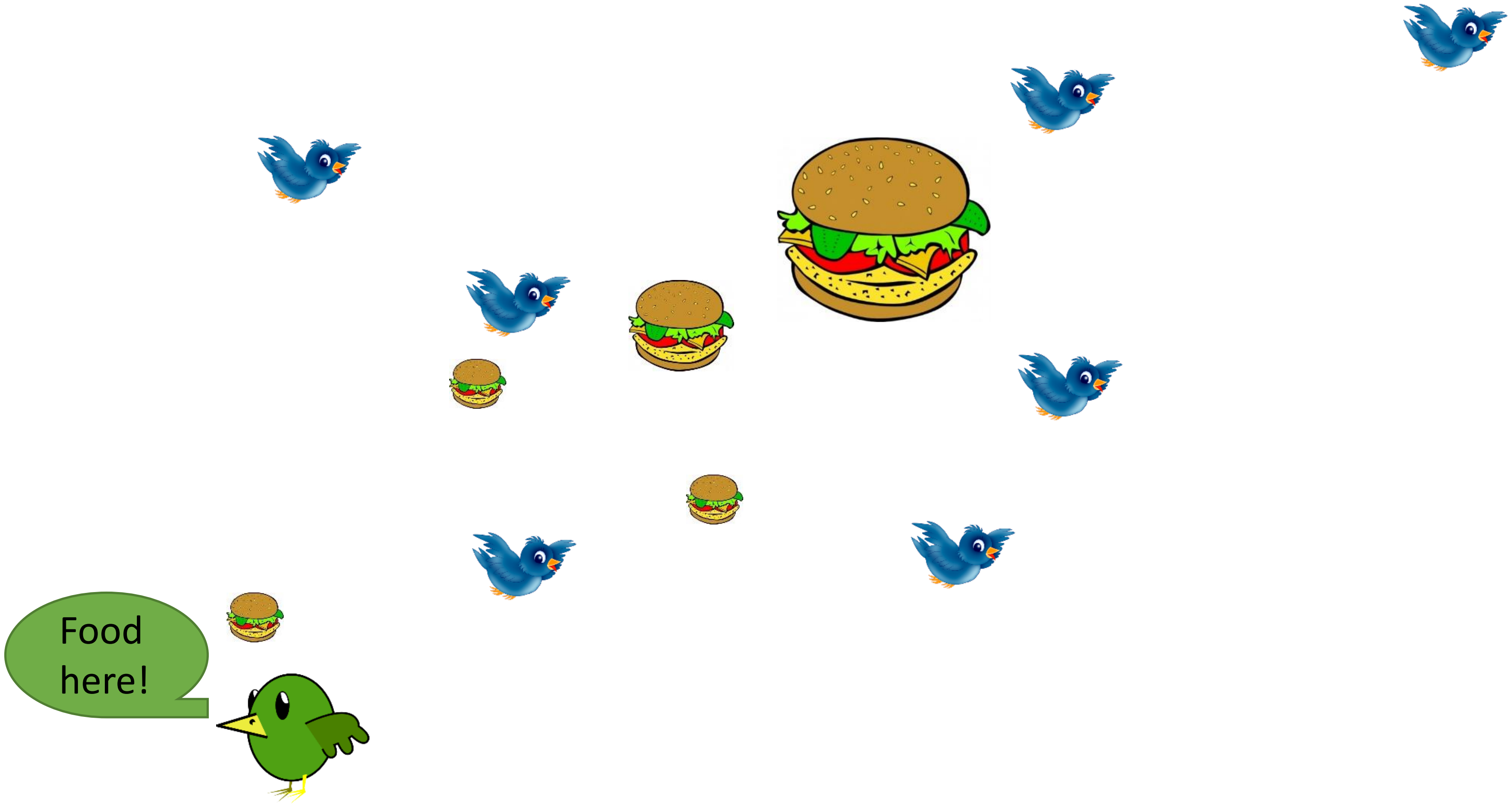
Motivation: Swarm Intelligence

As soon as one of them find food, it circles the food, and maybe yell and get fatter.



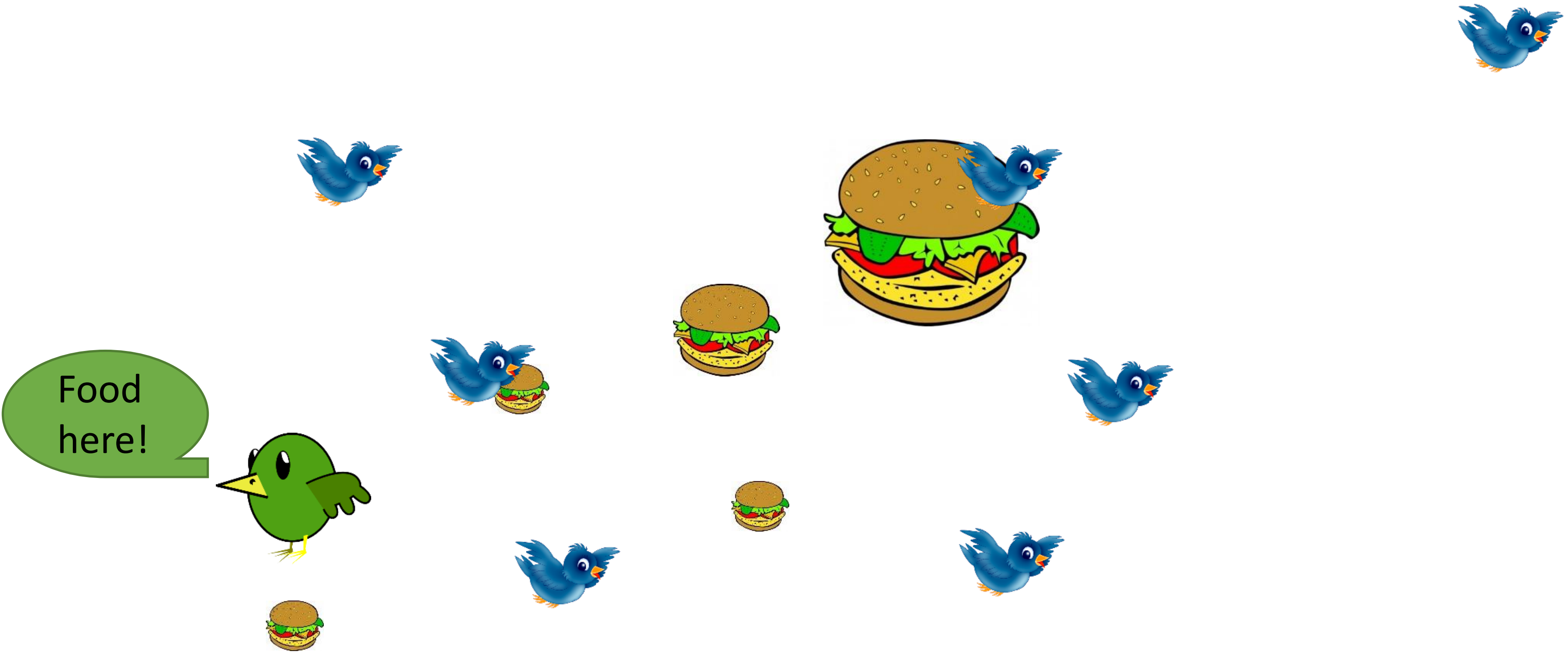
Motivation: Swarm Intelligence

Other birds then flock towards the noisy fat birdy.



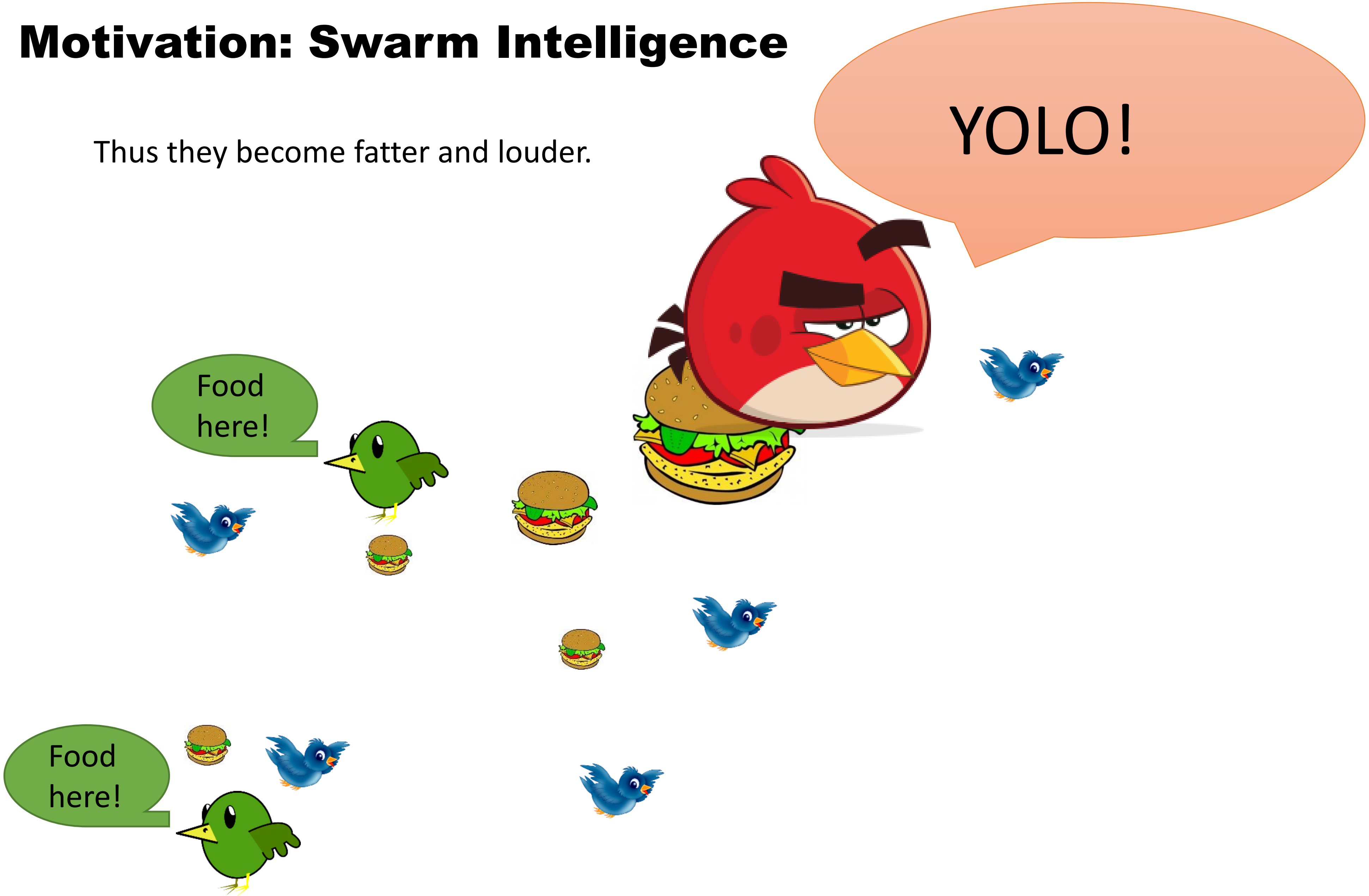
Motivation: Swarm Intelligence

On their way, they may find even more food.



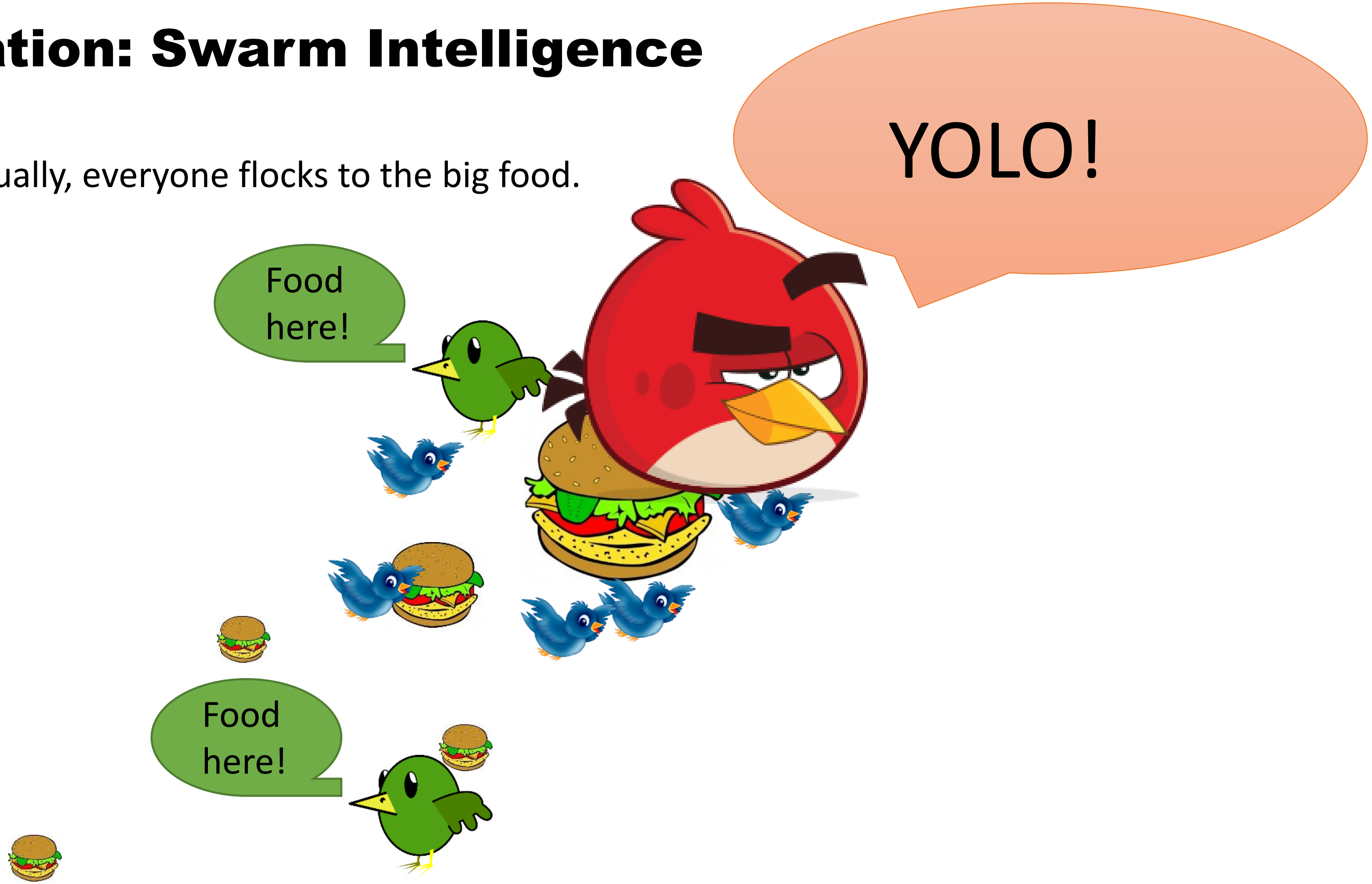
Motivation: Swarm Intelligence

Thus they become fatter and louder.

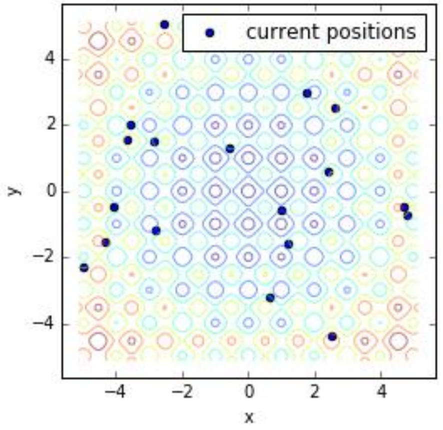


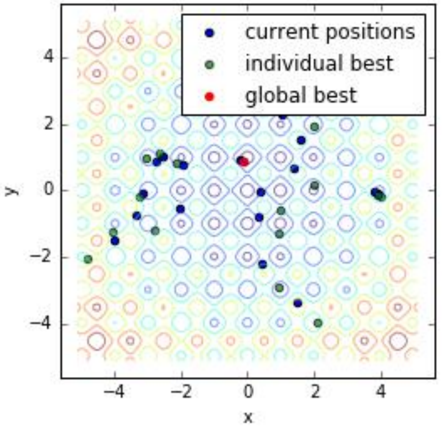
Motivation: Swarm Intelligence

Eventually, everyone flocks to the big food.



Algorithm: Flock to Past Best



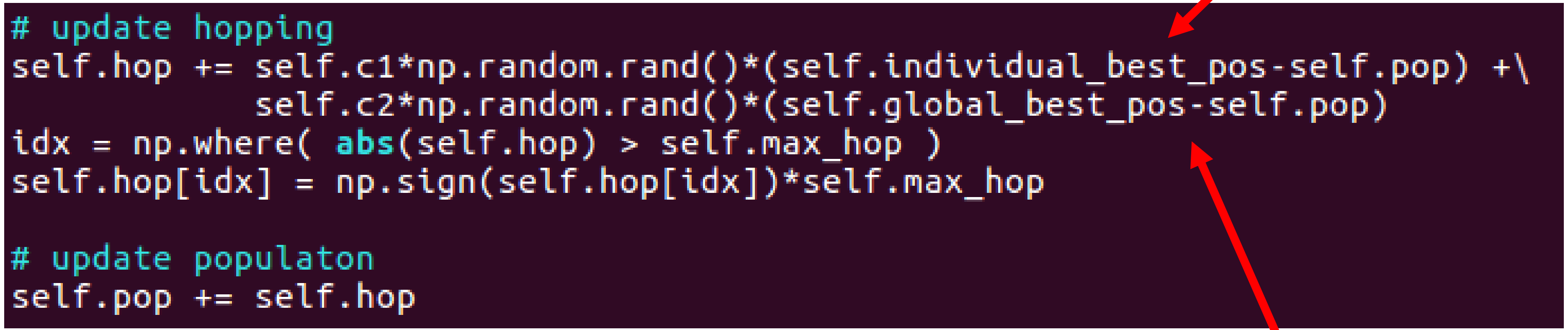


1. Initialize a number of samples from solution space.
2. Before some termination criteria is met:
   1. Evaluate “fitness” of each sample.
   2. Register “individual best” solutions.
   3. Select “global best” solution.
   4. Update each sample according to its individual best, the global best or a linear combination.
   5. Check convergence criteria.

Algorithm: Individual vs. Global Best

- c1 is the degree of individuality of each particle/sample - loner cowboy behavior
- c2 is the degree of submissiveness of each particle/sample - mindless minion behavior

Follow own experience



```
# update hopping
self.hop += self.c1*np.random.rand()*(self.individual_best_pos-self.pop) +\
            self.c2*np.random.rand()*(self.global_best_pos-self.pop)
idx = np.where( abs(self.hop) > self.max_hop )
self.hop[idx] = np.sign(self.hop[idx])*self.max_hop

# update populaton
self.pop += self.hop
```

Follow flock leader

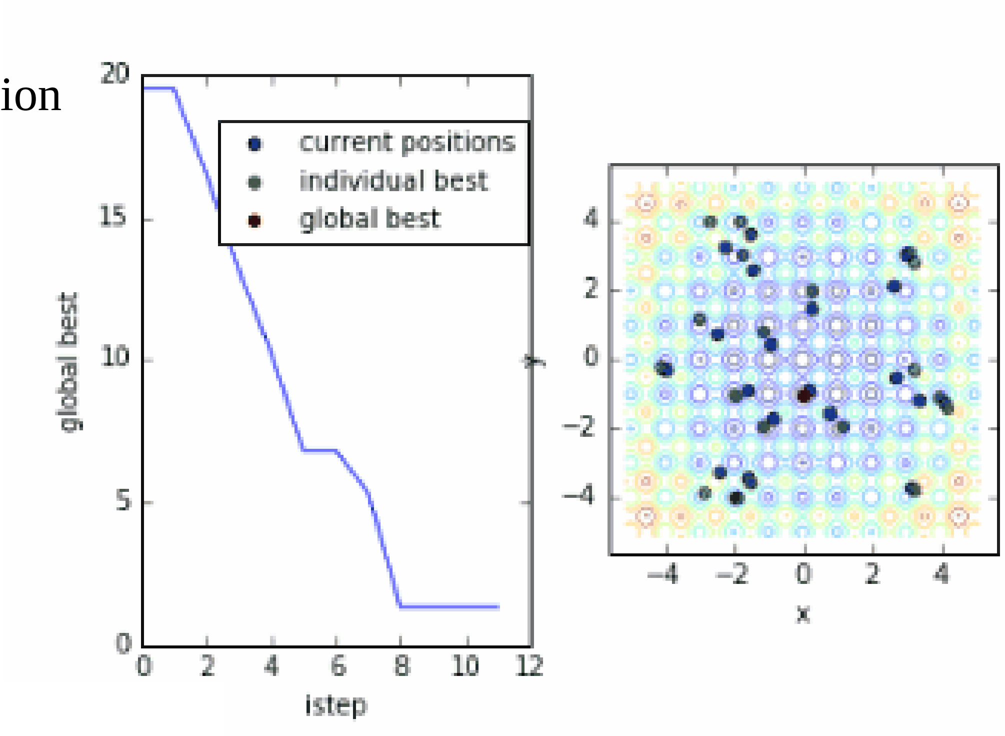
Example: Minimize 2D Rastrigin Function

- The Rastrigin function is multimodal and highly oscillatory function

$$\mathrm{Ras2D}(x,y) = 10\left[2 - \cos(2\pi x) - \cos(2\pi y)\right] + x^2 + y^2$$

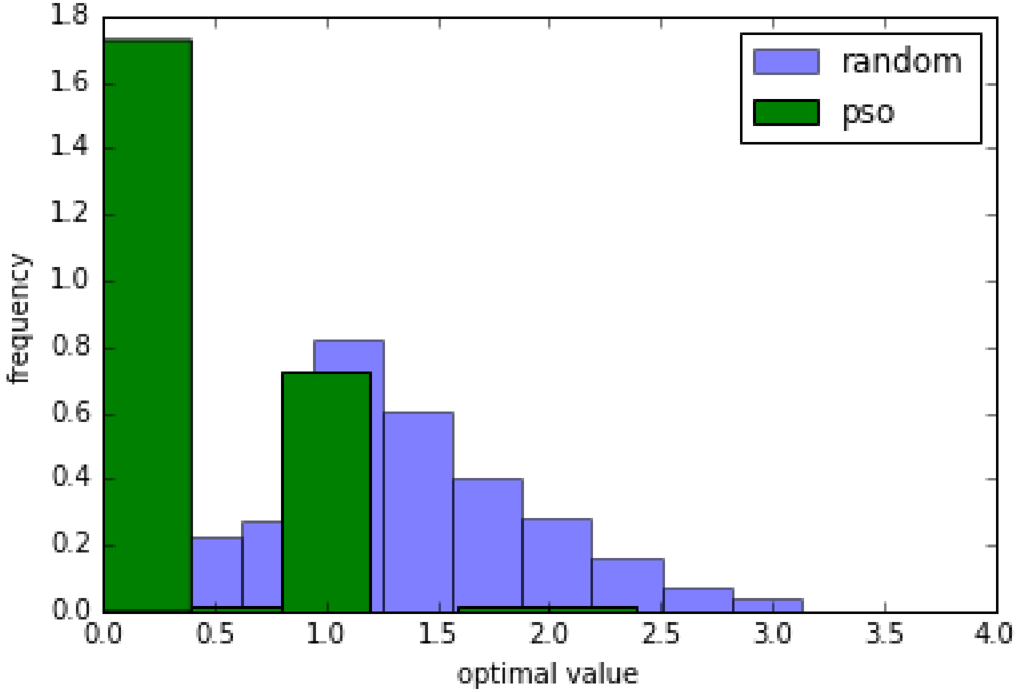
- Global minimum is at (0,0) with a value of 0

- Many local minima surround the global minimum.



Example: Minimize 2D Rastrigin Function

It’s better than random!



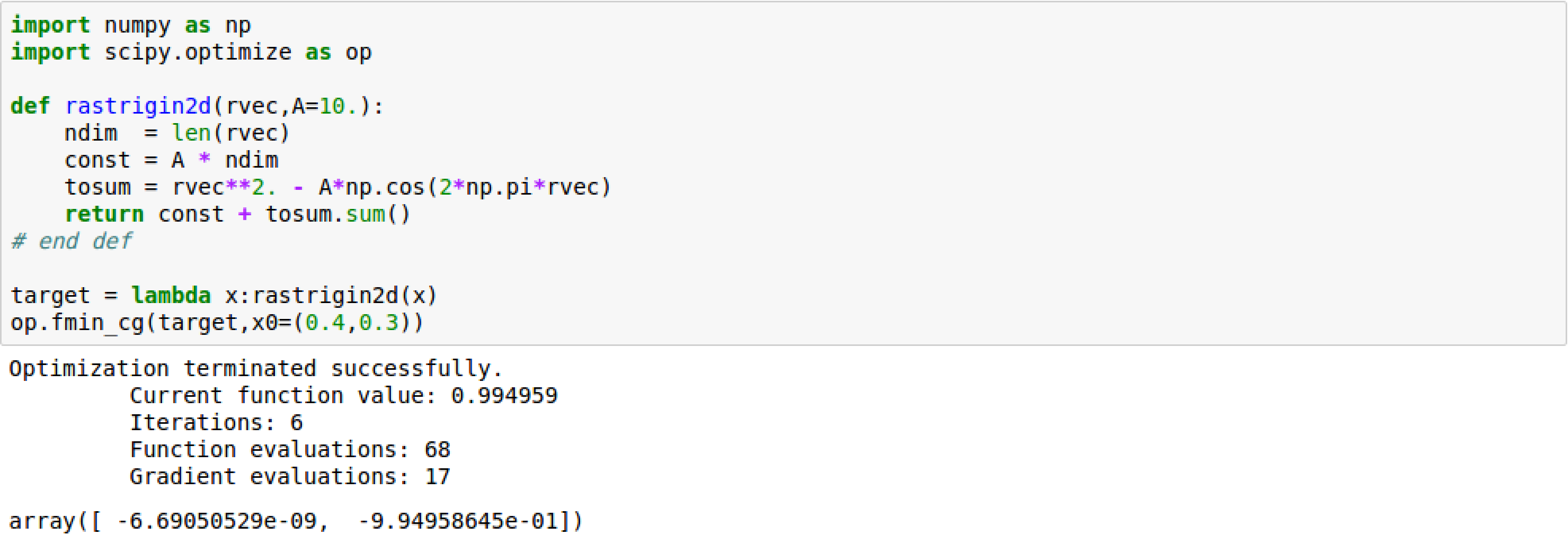
Why Particle Swarm Optimization (PSO) ?

- Easy to implement

- Does not require gradient

- Less likely to get stuck in a local minimum than deterministic algorithms

Example: Conjugate Gradient gets stuck in a local minimum of the 2D Rastrigin function.

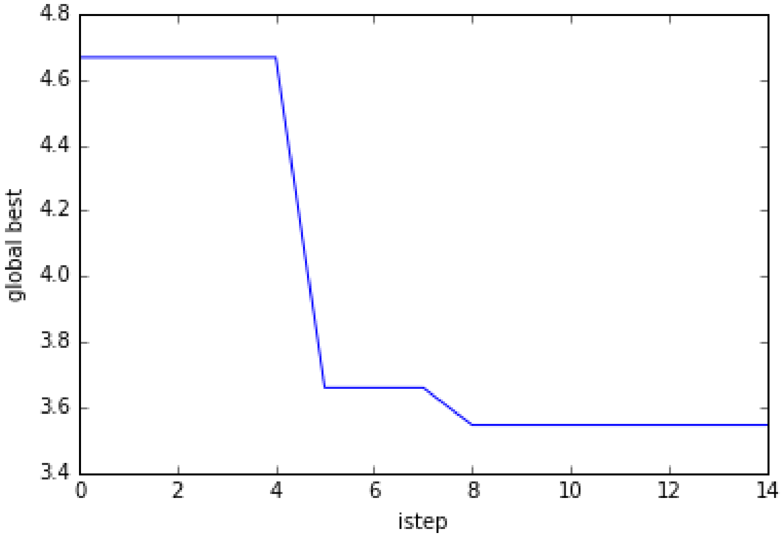


```
import numpy as np
import scipy.optimize as op

def rastrigin2d(rvec,A=10.):
    ndim  = len(rvec)
    const = A * ndim
    tosum = rvec**2. - A*np.cos(2*np.pi*rvec)
    return const + tosum.sum()
# end def

target = lambda x:rastrigin2d(x)
op.fmin_cg(target,x0=(0.4,0.3))
```

```
Optimization terminated successfully.
         Current function value: 0.994959
         Iterations: 6
         Function evaluations: 68
         Gradient evaluations: 17

array([ -6.69050529e-09,  -9.94958645e-01])
```

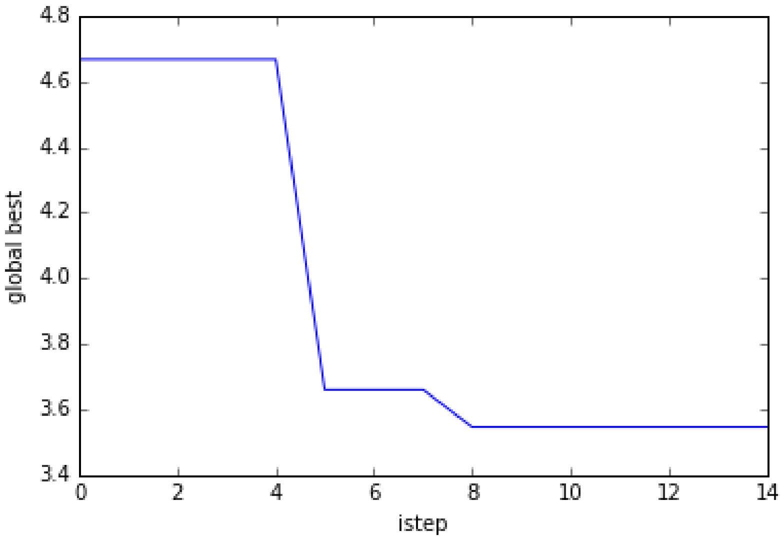
Gotcha! How to Determine Convergence?

Is this converged?



Gotcha! How to Determine Convergence?

Psyche! No!



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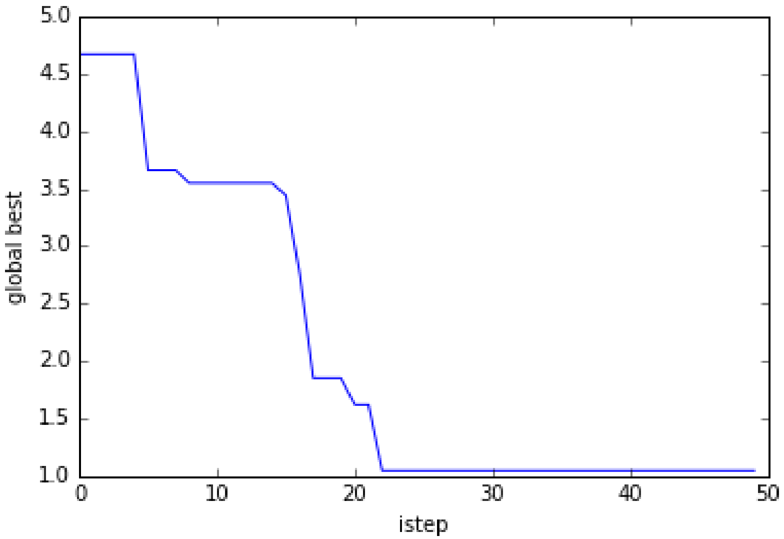

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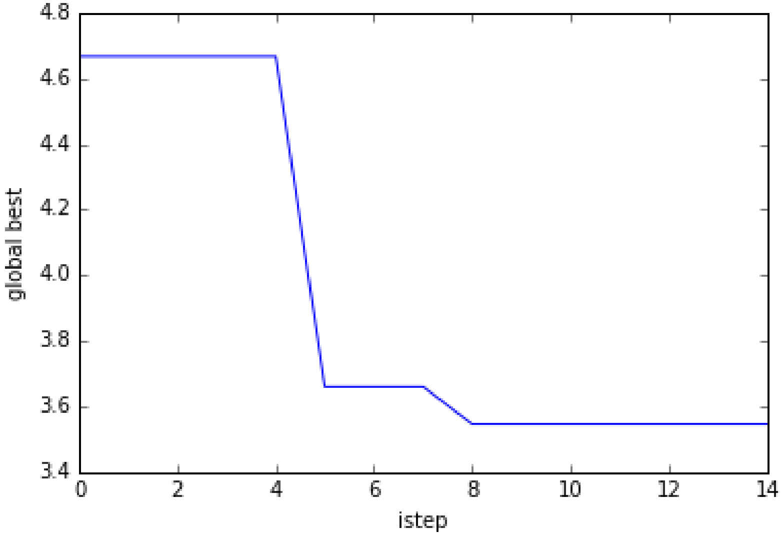

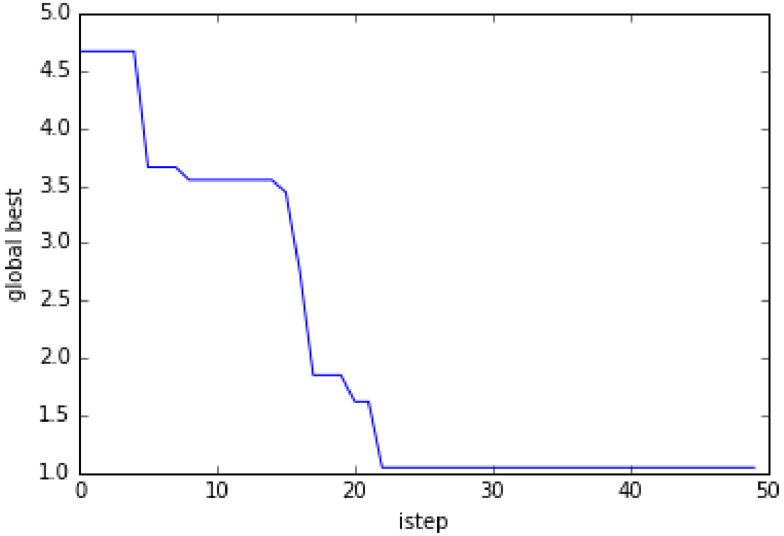

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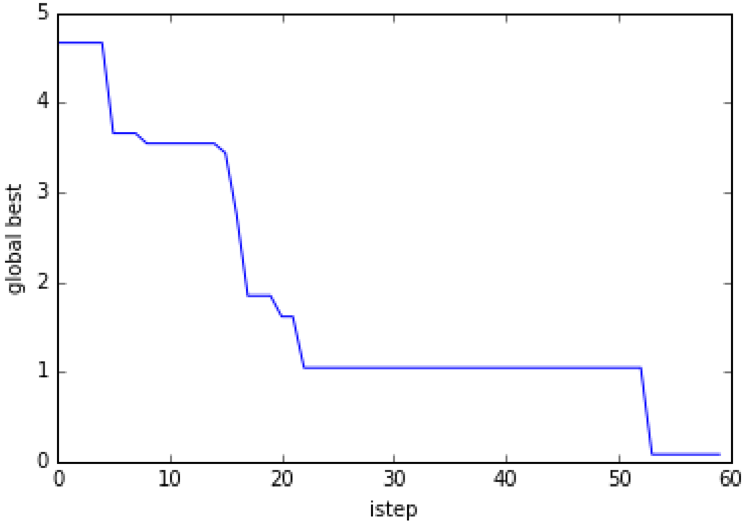
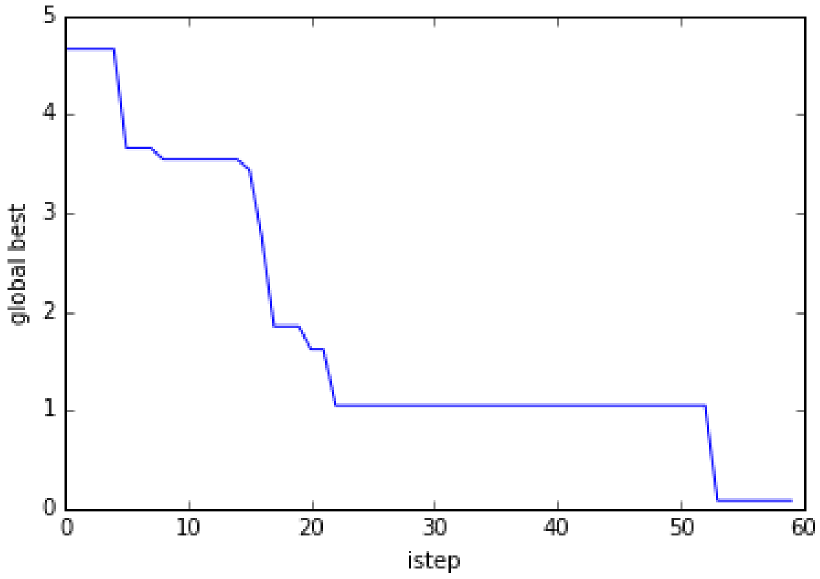


How to Determine Convergence? Sign Test? Hop Trace?

Feed global best trace into a sign test

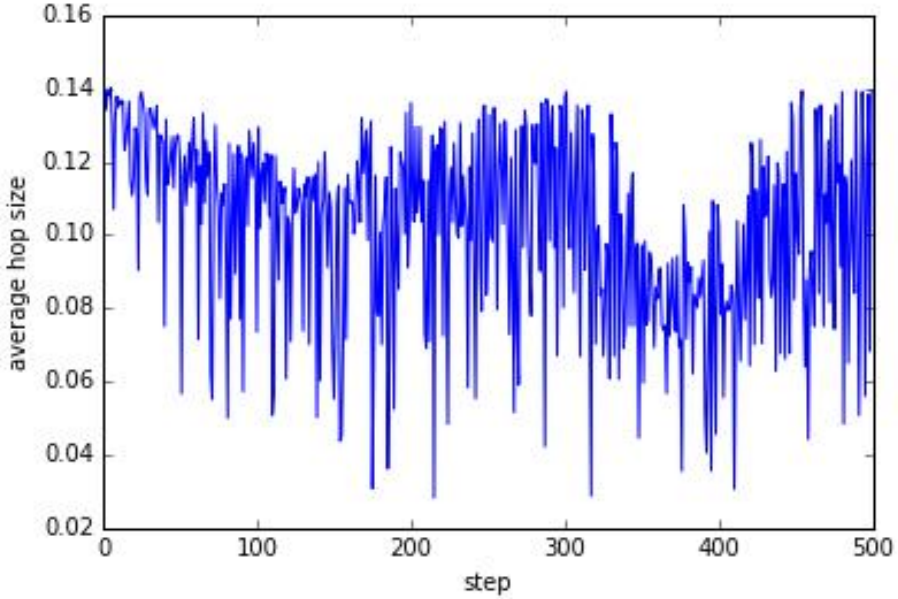
Kwok et. al., IEEE, CEC (2007)

This basically counts the number of times global best is not improved.



Calculate moving correlation for average hop trace

Yang (2016) ?



Application to the Bin Packing Problem

Ingredients in PSO: naïve application

- Population of Solutions ✓ : a collection of greedy solutions
- Individual and Global Best ✓ : highest packing fraction solution
- Hopping update ???? : How to hop “towards” individual or global best?

Application to the Bin Packing Problem

Ingredients in PSO: modified PSO

- Population of Solutions ✓ : a collection of greedy solutions
- Individual and Global Best ✓ : highest packing fraction bin
- Hopping update: Liu et. al., IEEE, CEC (2006)

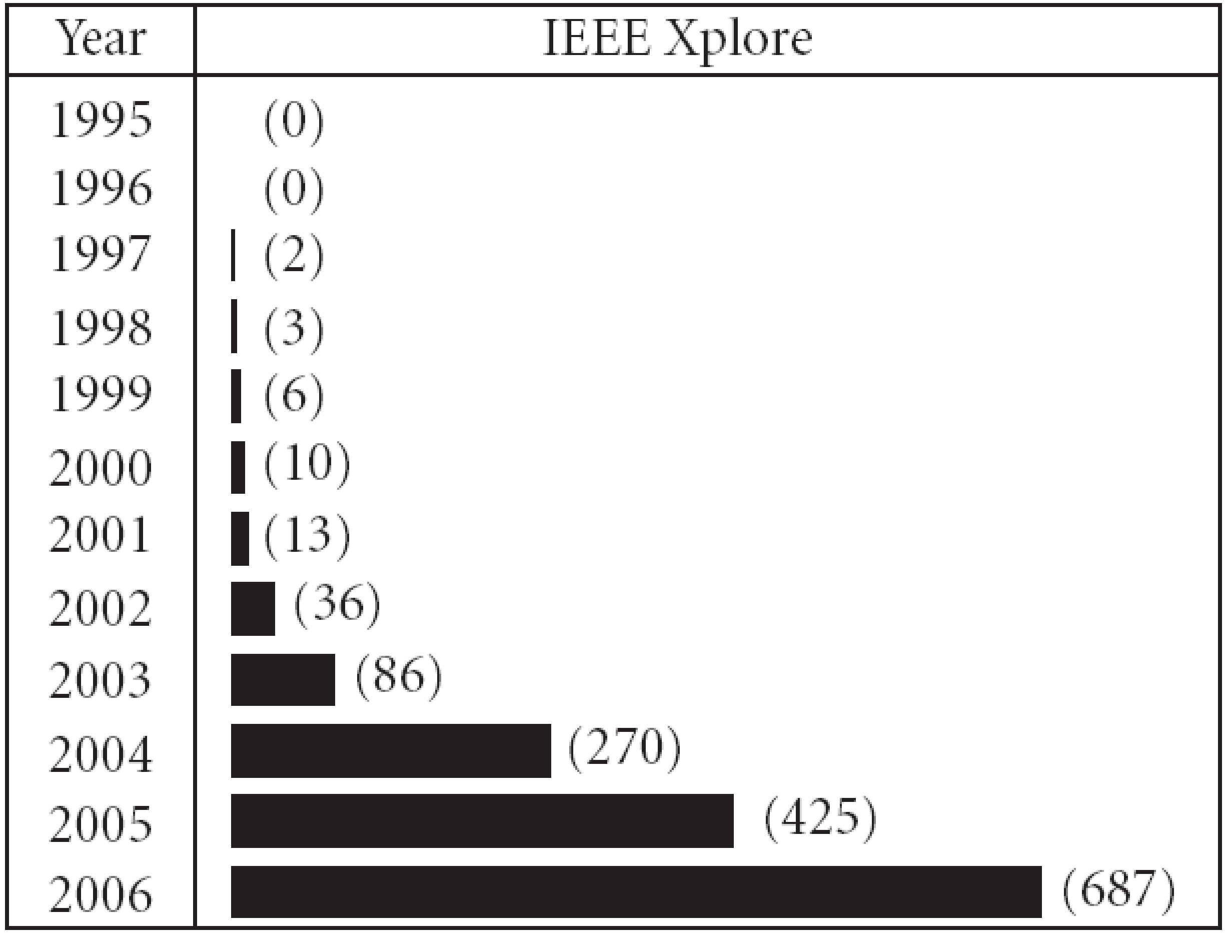
Hop towards individual best: use best bin from personal history
Hop towards global best: use best bin from global history

Application to the Bin Packing Problem

Coming “Soon”

Real World Applications:

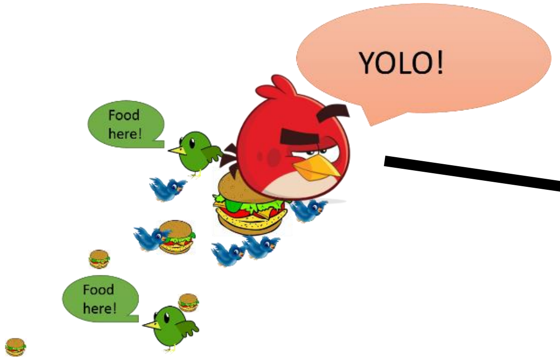
- Antenna Array Design
- Biomedical
- Communication Networks
- Clustering and Classification
- Combinatorial Optimization
- Distribution Networks
- Electronics and Electromagnetics
- Engines and Motors Efficiency Optimization
- Fuzzy and Neurofuzzy: fuzzy control, fuzzy classification
- Graphics and Visualization
- Scheduling



Poli, JAEA, **2008**, 685175 (2008)

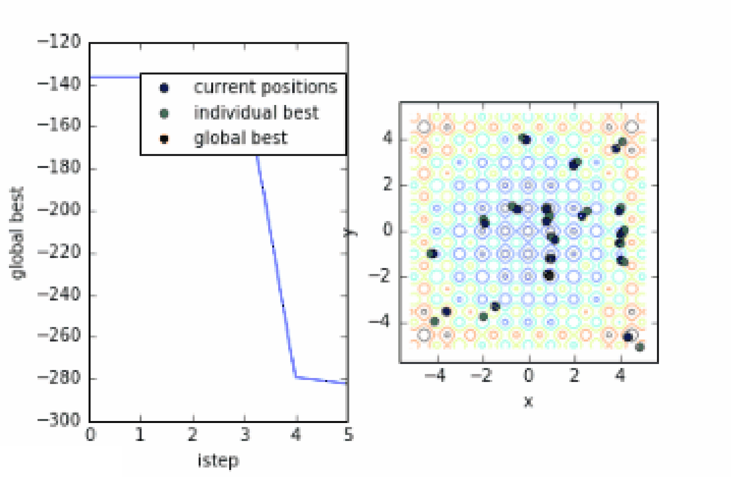
Conclusions:

- PSO is a nature (swarm intelligence) inspired optimization algorithm



nature

algorithm



- PSO is easy to implement, requires no gradient, and tend to get out of local minima

- PSO has many applications and enjoys a rising level of interest