Unified Swarm Intelligence

Yuhui Shi, PhD, IEEE Fellow
Shenzhen Key Lab on Computational Intelligence
Department of Computer Science and Engineering
Southern University of Science and Technology

Outlines

1) Introduction
2) Developmental swarm intelligence
3) Innovation-inspired Optimization Algorithms
4) Unified Swarm Intelligence
5) Conclusions

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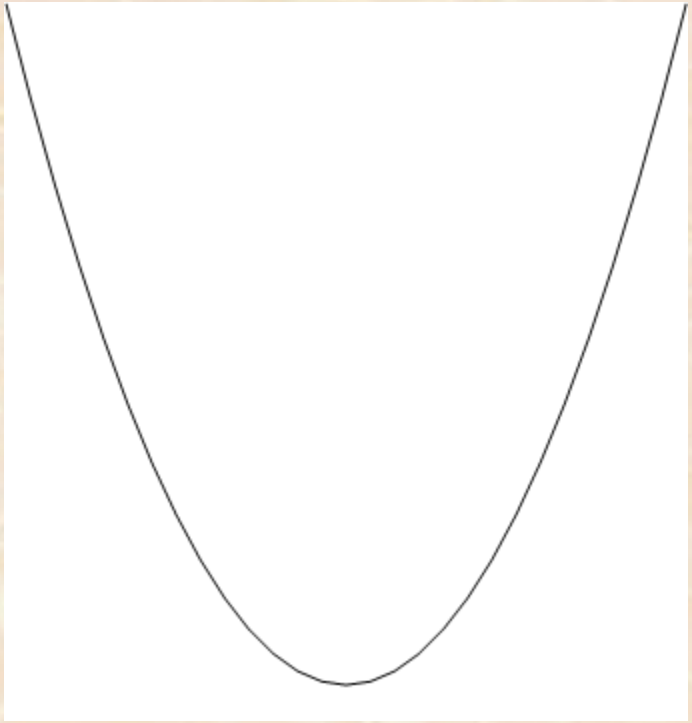
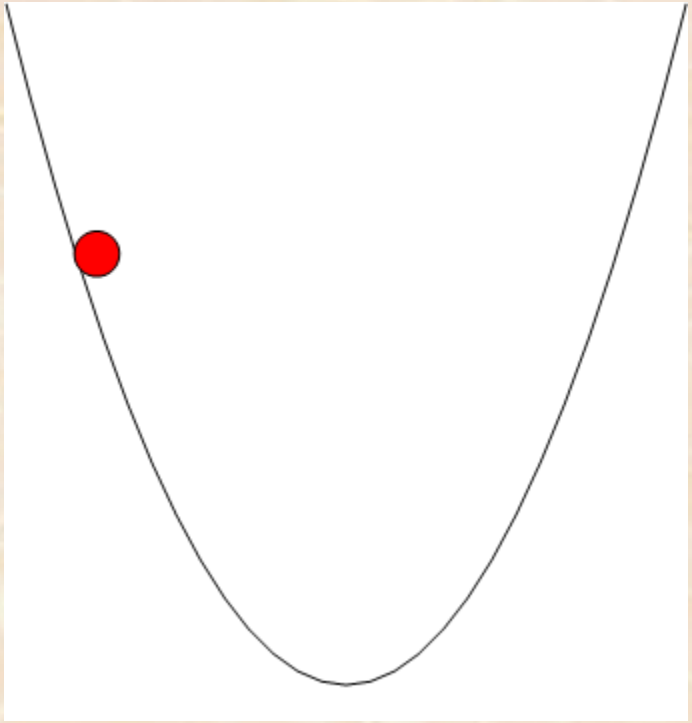




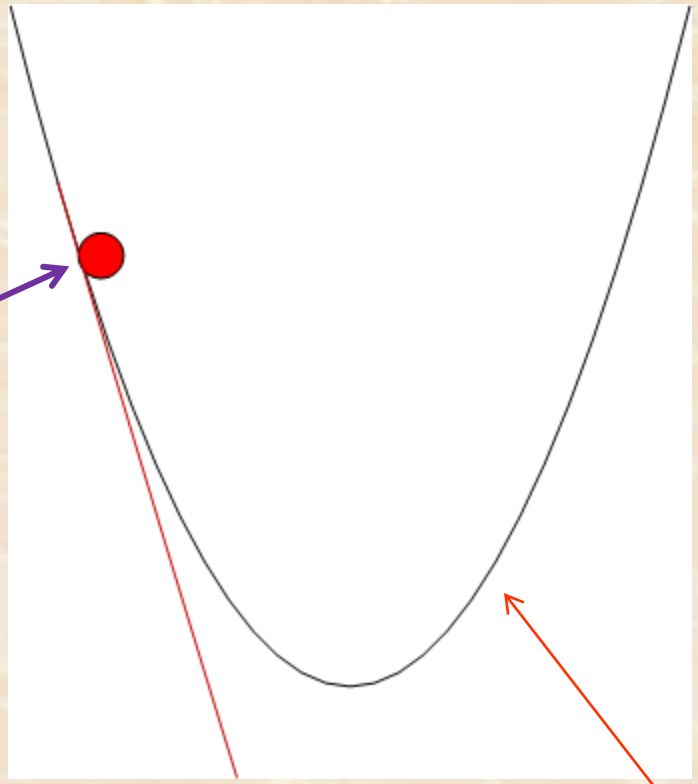
method of steepest descent

one takes steps proportional to the *negative* of the gradient

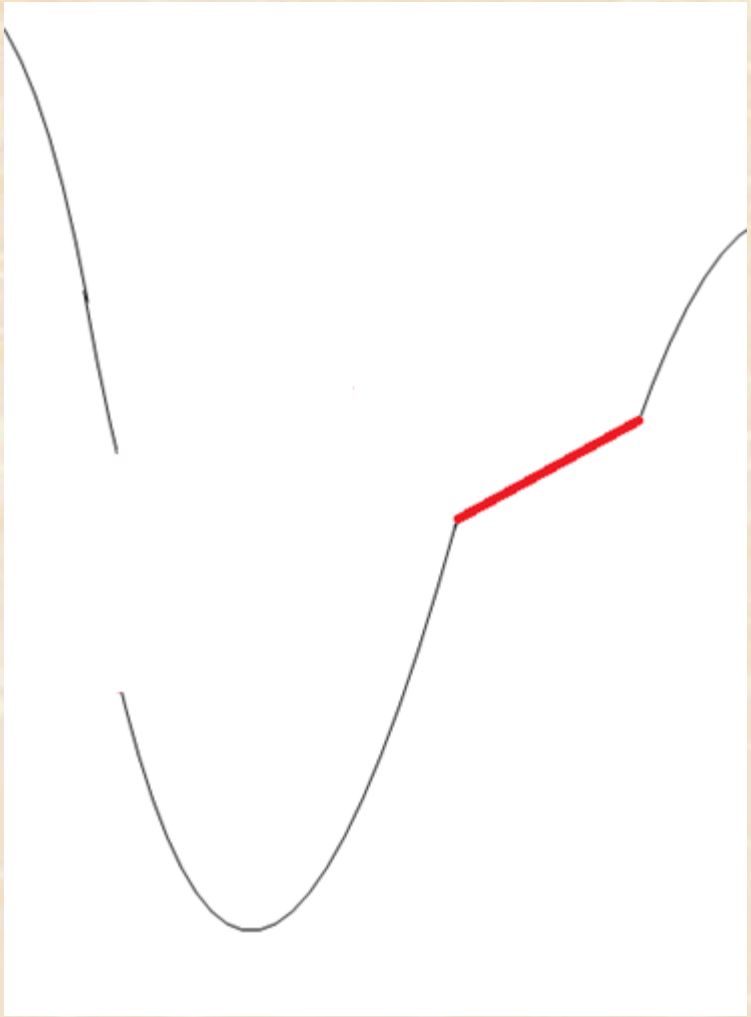
$$\mathbf{b} = \mathbf{a} - \gamma \nabla F(\mathbf{a})$$

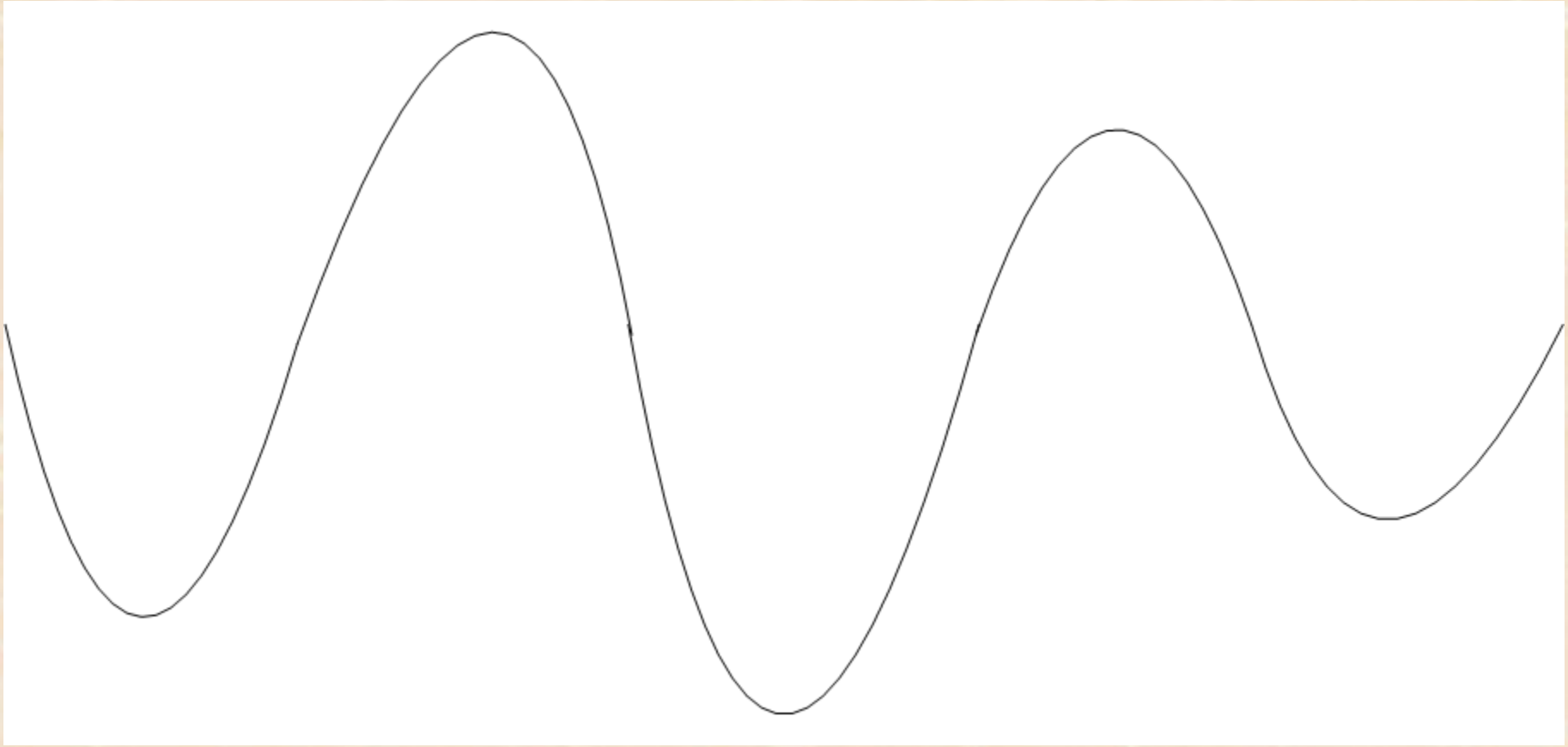
For $\gamma \to 0$ a small enough number, then

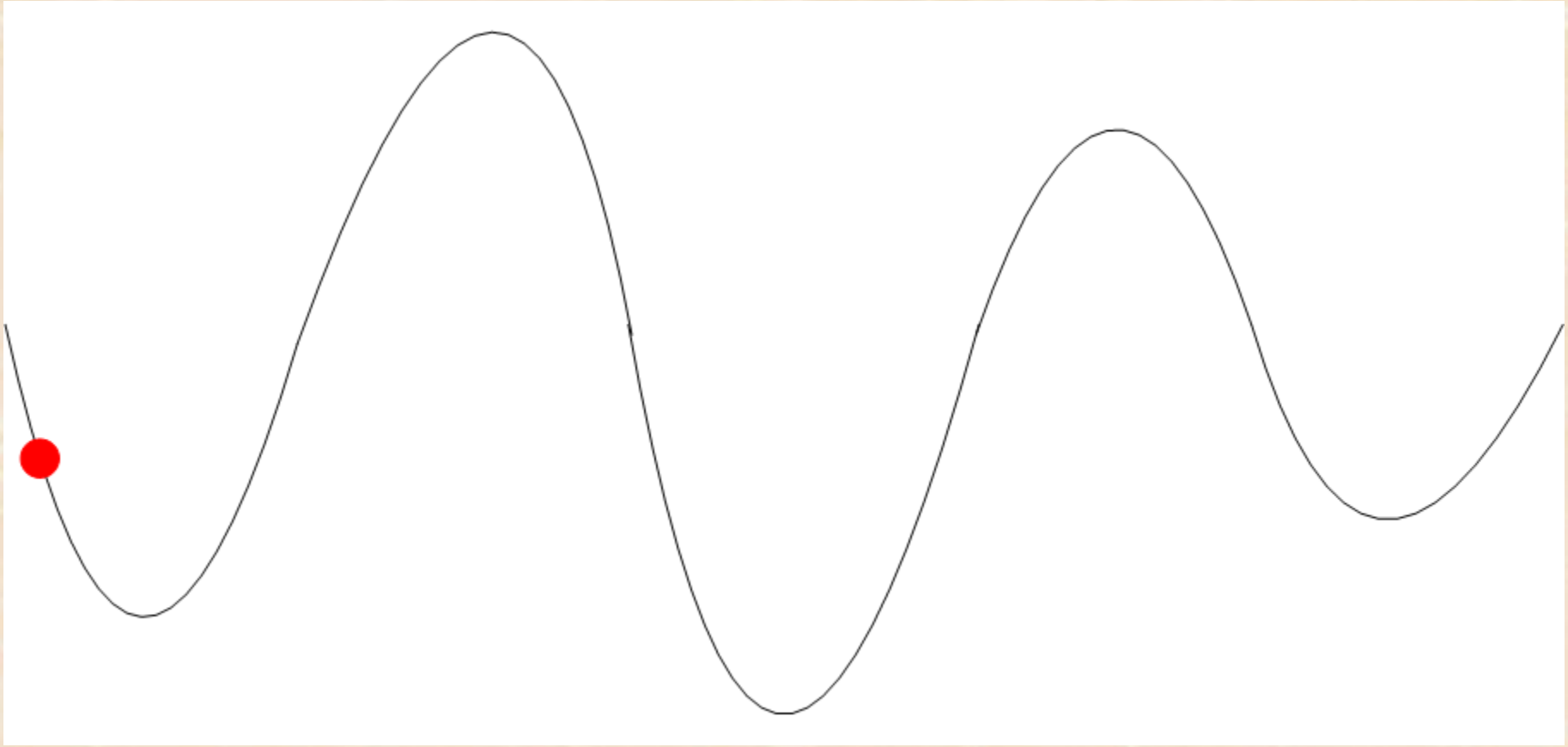
$$F(\mathbf{a}) \geq F(\mathbf{b})$$

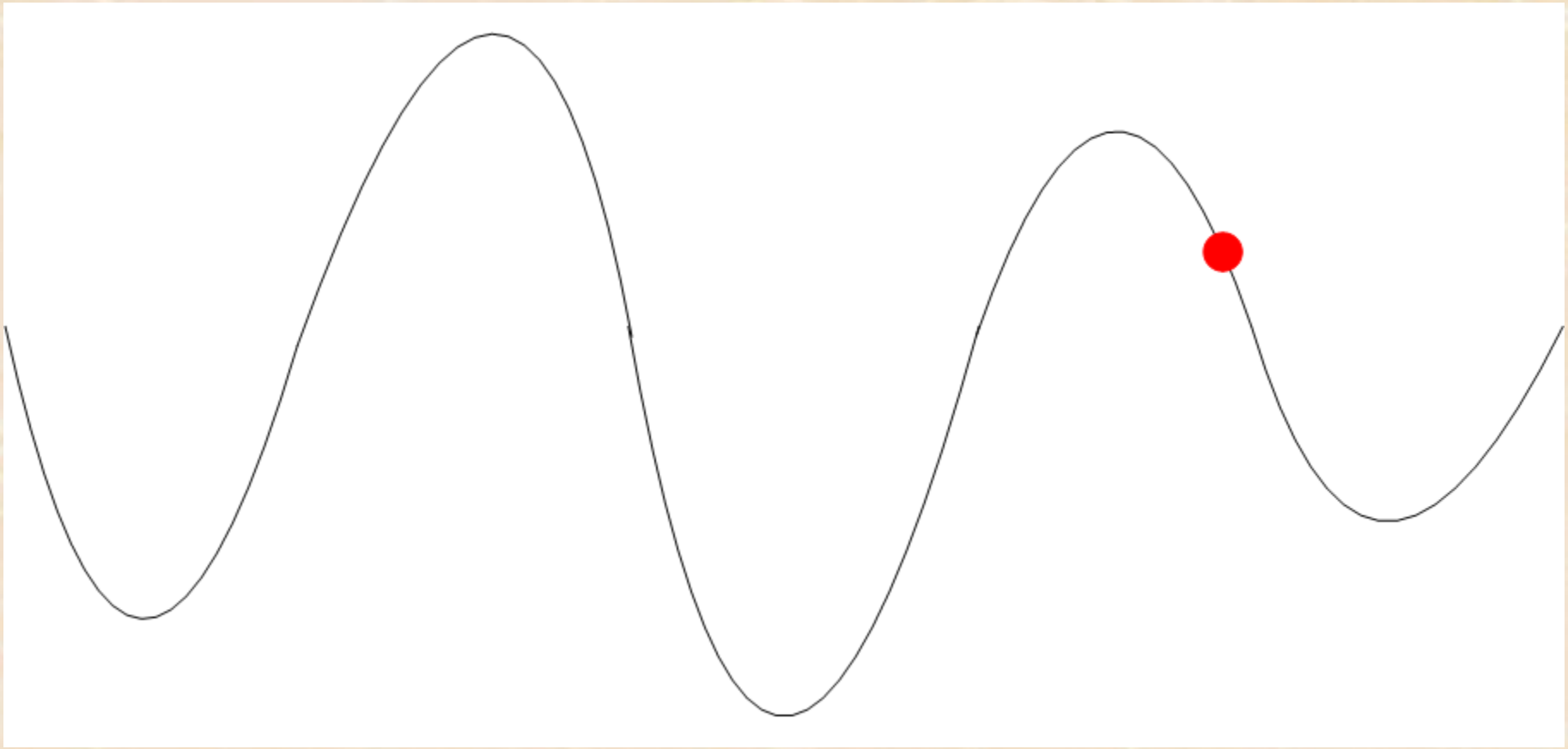


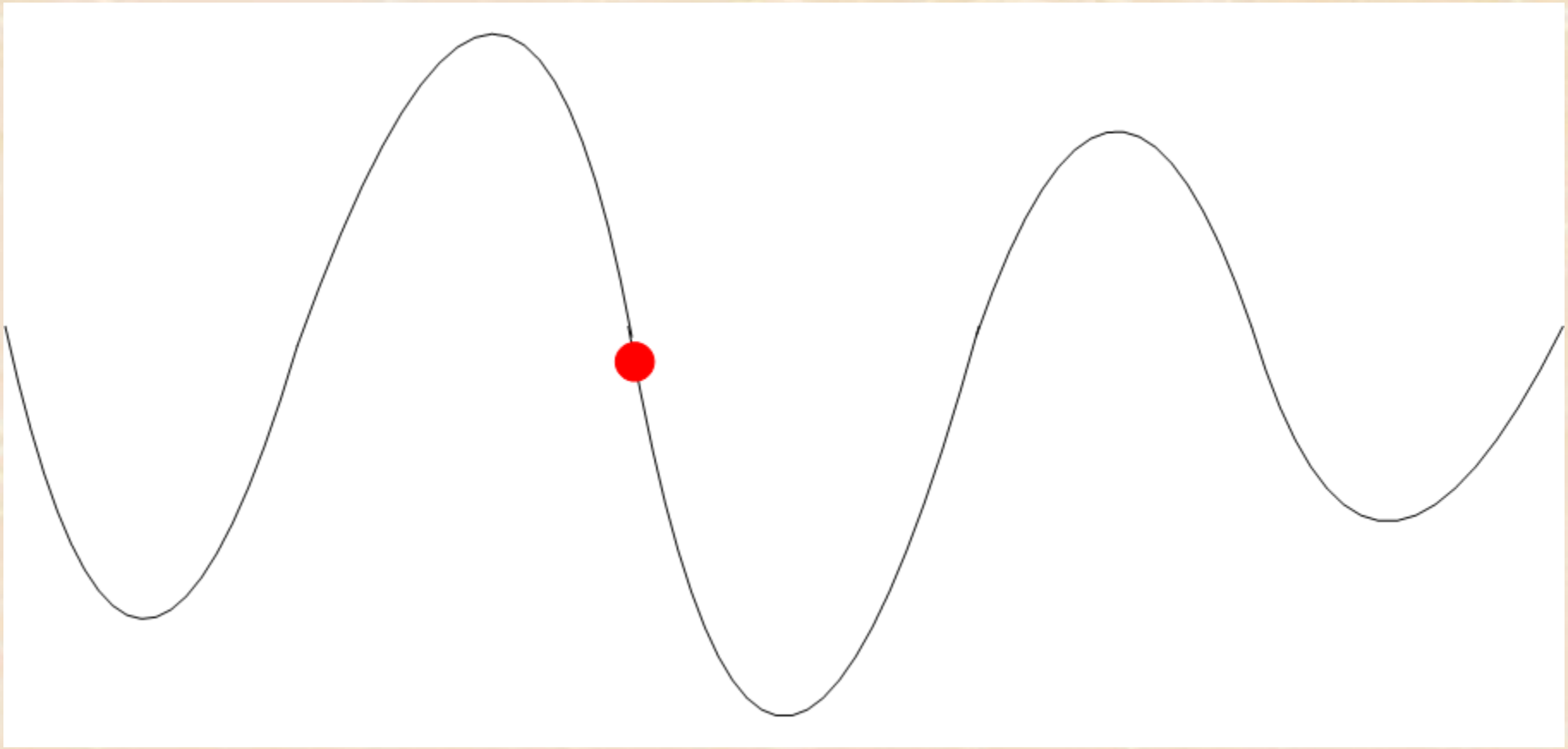
Mapping f: a → b;



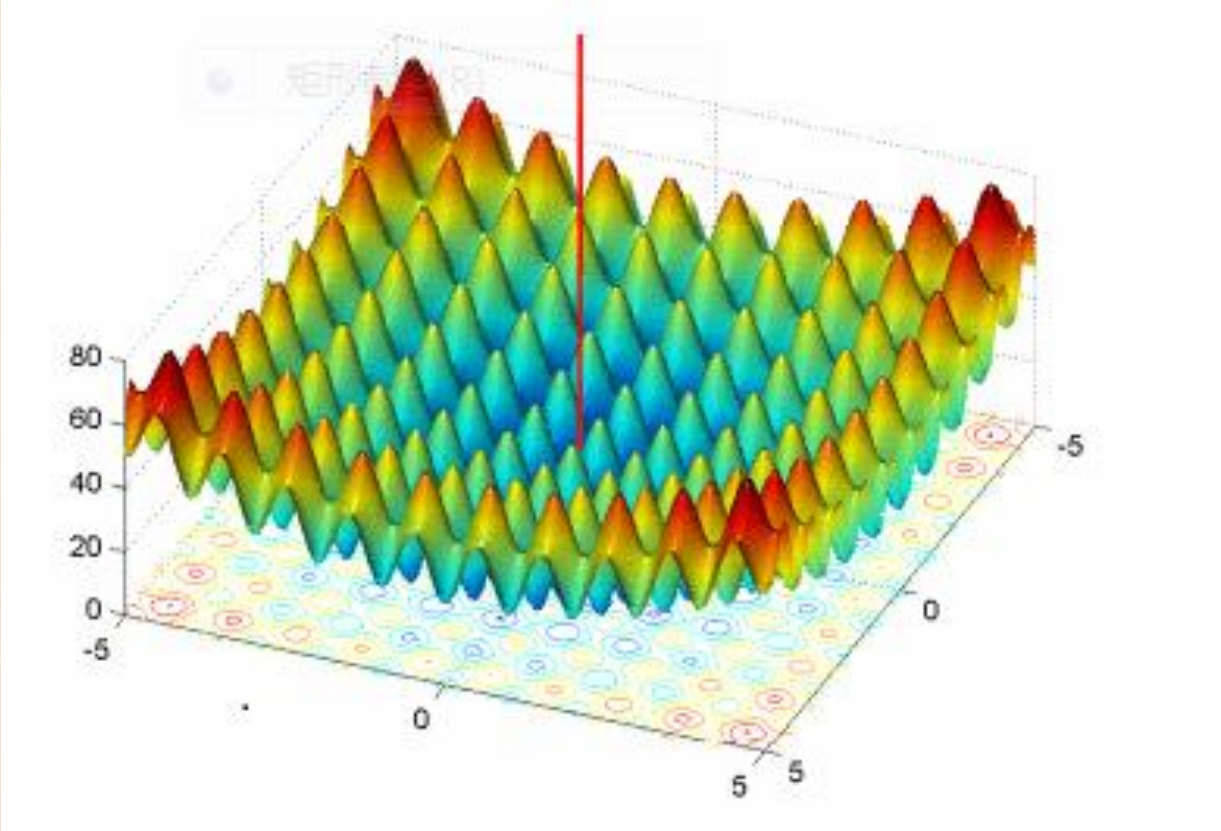




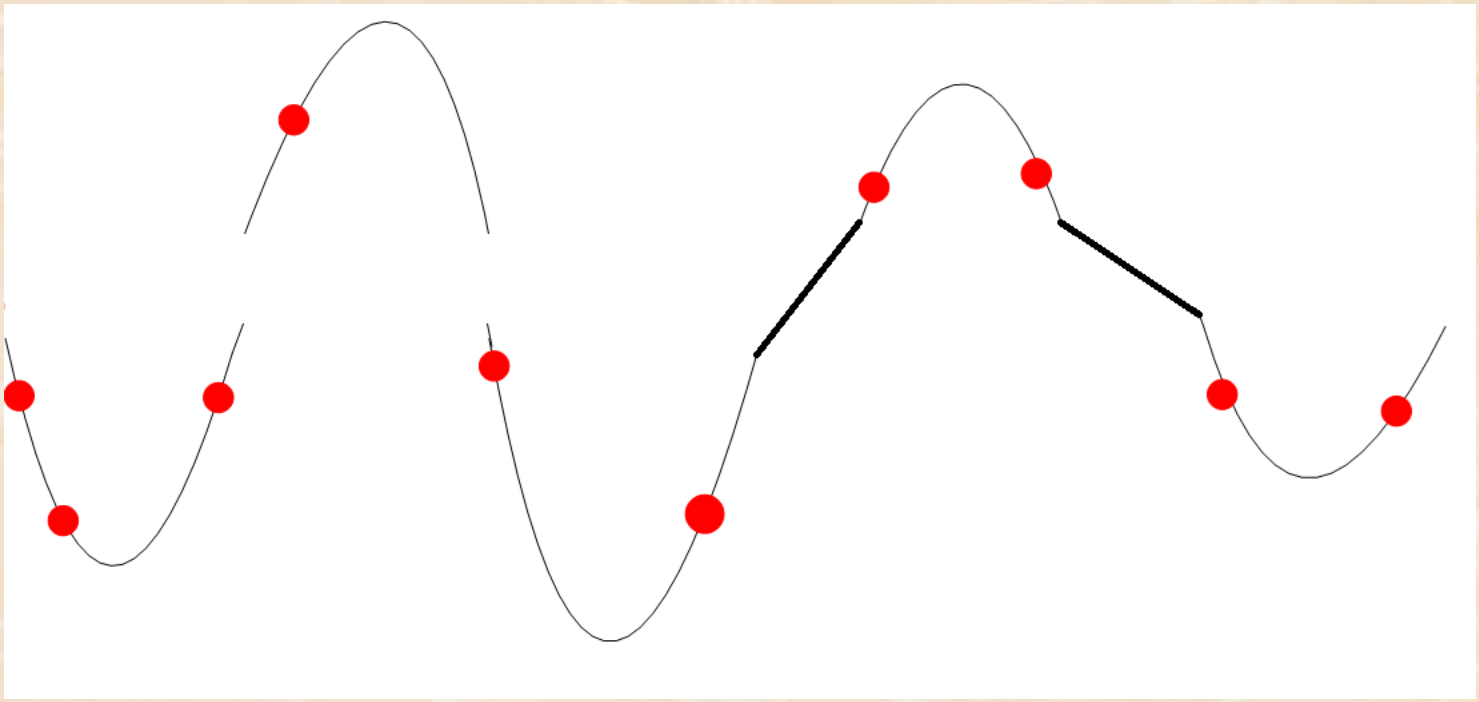




Rastrigin	$f_7 = \sum_{i=1}^{d} [x_i^2 - 10\cos(2\pi x_i) + 10]$	$[-5.12, 5.12]^d$



Not know where should move to?
Avoid Misleading → Add noise → exploration vs. exploitation

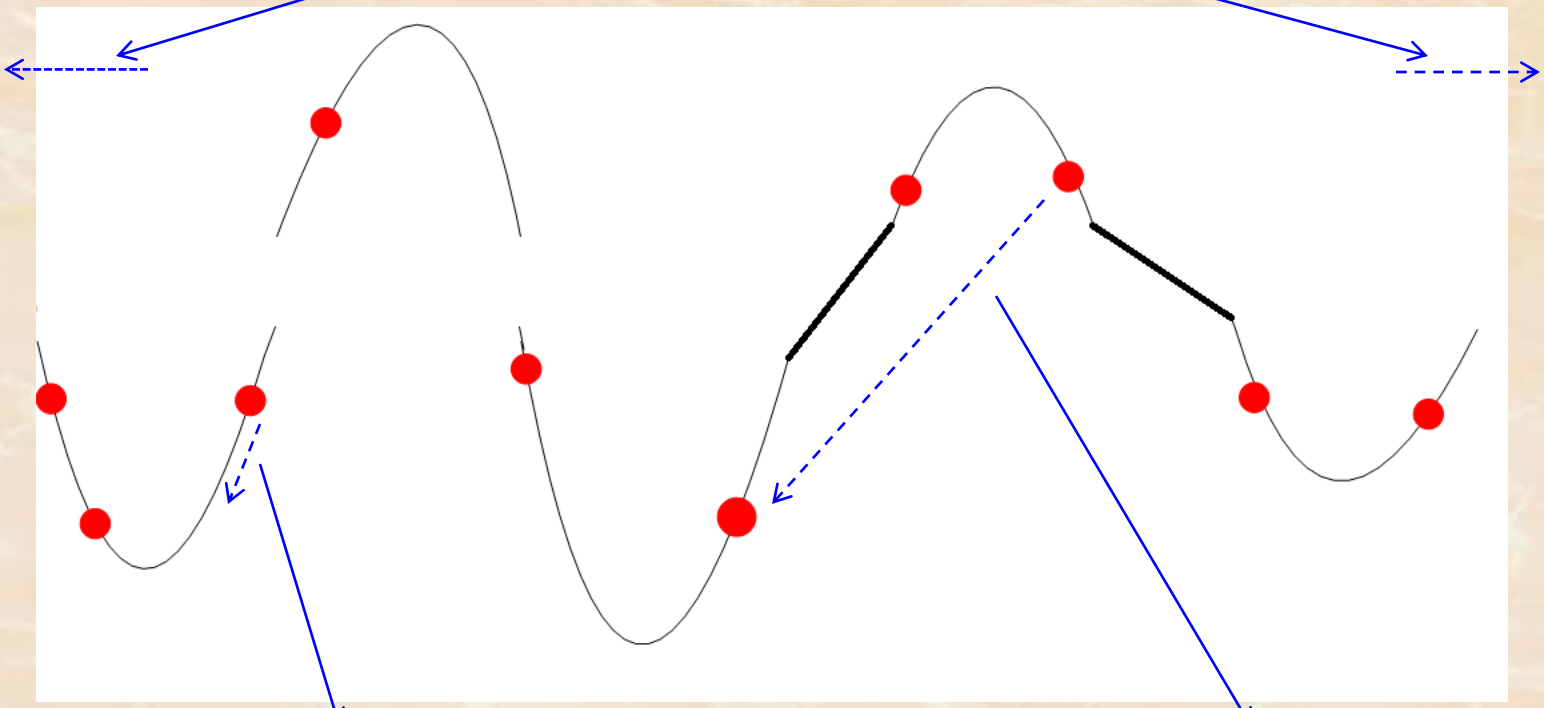


Different methods use different mapping functions ← Population-based methods

↑

$f(x_1,x_2,\ldots,x_{10}) \rightarrow x_1,x_2,\ldots,x_{10}$ ⟶ Design the mapping function f(.)

Exploring: disrupting cluster center in BSO



Emulating, e.g. mutation in GA

Learning, e.g. PSO

exploration vs. exploitation

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The Law of Sufficiency

If a solution to a problem is:

- Good enough (it meets specs)
- Fast enough
- Cheap enough

then it is sufficient.

Not necessary to be the global best solution

For lot of times, we even don't know where and whether there is a "BEST" solution existed

Existing Population-Based Algorithms

- Evolutionary Algorithms
  - ✓ Genetic algorithms
  - ✓ Evolutionary programming
  - ✓ Evolutionary Strategy
  - ✓ Genetic Programming
- Swarm Intelligence
  - ✓ Ant Colony Optimization
  - ✓ Bacterial Foraging Algorithms
  - ✓ Brain Storm Optimization Algorithms
  - ✓ Cultural Algorithms
  - ✓ Fish School Optimization
  - ✓ Particle Swarm Optimization
  - ✓ etc.

Swarm Intelligence:

A group of optimization algorithms that are inspired by

a group of objects

emerges a global intelligent behavior

through decentralized、through local interaction

emerges a global intelligent behaviors

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Learning usually develop or happen at different levels

In general, two levels of learning,

- one is at top or macro level at which “structure” or capacity of learning is formed,
- the other is at the bottom or micro level at which the actual learning (or learning capability) is conducted,

These two levels recycle back and forth, therefore, the learning is developmental.

Developmental learning can also be looked as two layer learning or hierarchical learning,

- one is learning itself (or learning capability at micro level),
- the other is to develop the learning capacity (at macro level).

Five examples of the developmental learning :

- Brain Evolution;
- Brain Development;
- Learning to Learn;
- Thinking of Thinking;
- Brainstorming Process.

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Brain Evolution

The size of human brain has tripled across nearly seven million years and its neocortex has expanded also

With the brain size enlarging and neocortex expanding, it is natural to think

- the learning capacity of the human brain has been being developed to enable human brain to have better learning capability
- or in better position (potentiality) to learn.

On other words, brain evolution can be considered as

- developing brain's learning capacity
- while every human being is born to have the capability to learn with the learning capacity possessed by the evolved brain at that time

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Brain Development

A child is born to have almost all the neurons, but the brain itself is still under development **for a while** during which the nervous system will be developed.

It is natural to believe it is the developed nervous system that will determine the child's **learning capacity** to learn knowledge throughout his/her lifetime.

If some harmful things happen, such as illness, during the time of nervous system development, which may cause the nervous system not fully developed, then the child will have developmental **learning disability**, that is to say, he/she is able to learn but with disability or lessened capacity.

On other words, brain development of each child can be considered as being responsible for developing his/her **learning capacity** with which he/she has the **learning capability** to learn.

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Learning to Learn

Everyone is born to be able to learn, but not everyone will become equally knowledgeable.

How knowledgeable a person is and in what areas depends on his learning experience and learning attitude.

- If a person has the interests/attitudes to learn and he/she has followed a good learning approach
- and furthermore has had the luck to learn from experienced and great teachers,
- in general, he/she will eventually become more knowledgeable than others.

To help children and/or students to enhance its capacity to learn,

schools are built,
textbooks are written,
teaching methods are taught to teachers to follow,
and learning approaches or methodologies are introduced to students to guide them to learn.

That is to say, the society is doing its best to enhance everyone's capacity to learn.

Learning to learn will help develop a person's learning capacity so that he/she can be a better learner with his/her learning capability.

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Thinking of Thinking

Any two persons may have the same knowledge about one problem, but one may be better than the other when asked to solve the problem because the two persons may look at or think the problem from different angles.

A problem may be easier to be solved when being looked at from one perspective (angle). Therefore, it is important and even critical to learn the way to think.

In order to solve a problem you can't solve at beginning, you should keep on thinking the problem **from different perspective**.

The knowledge you have is your **thinking capability**, while the way of your thinking is your **thinking capacity**.

You should learn both the **knowledge**, that is your thinking capability, and **the way you think**, that is your thinking capacity.

Brainstorming Process

It is the experts themselves who will eventually solve the problem;

Experts should have the **capability** to solve the problem;
Other persons involved in the brainstorming problem are there to improve the **capacity** of the experts.

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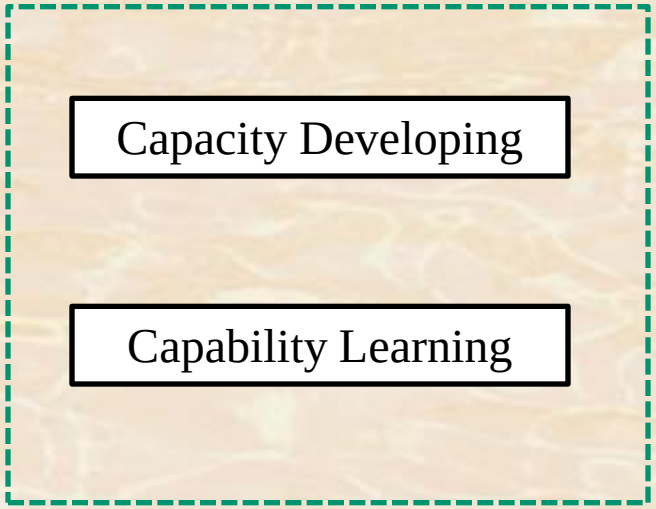

Framework of Developmental Swarm Intelligence (DSI)
and/or Framework of Developmental Learning Algorithms (DLA)

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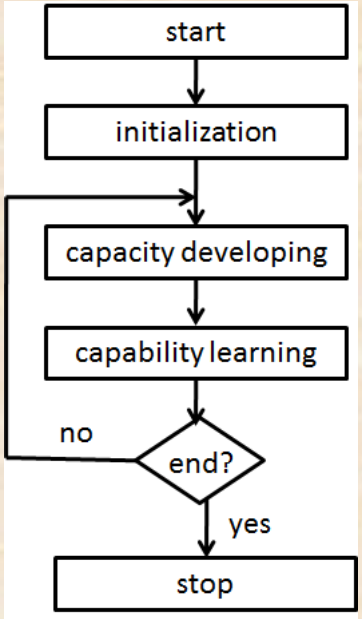

A flowchart of a developmental swarm intelligence algorithm

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Innovation

Innovation is about changes

three levels of innovation:

at the learning level,
at the emulating level, and
at the exploring level

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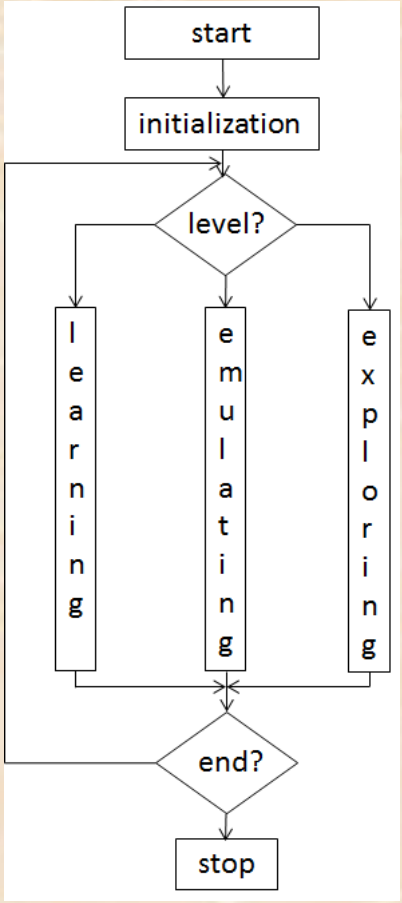
Innovation-Inspired Optimization Algorithm



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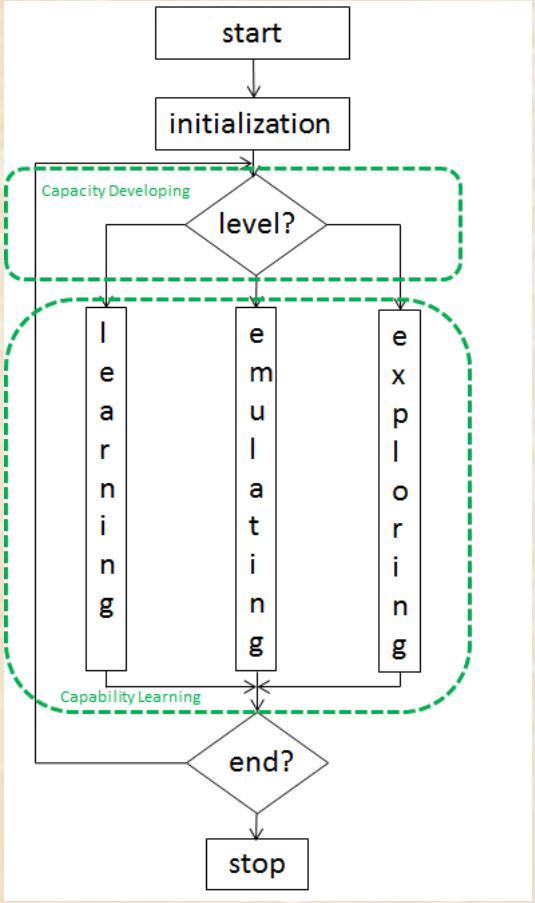
Developmental Learning Perspective for Innovation-Inspired Optimization Algorithm



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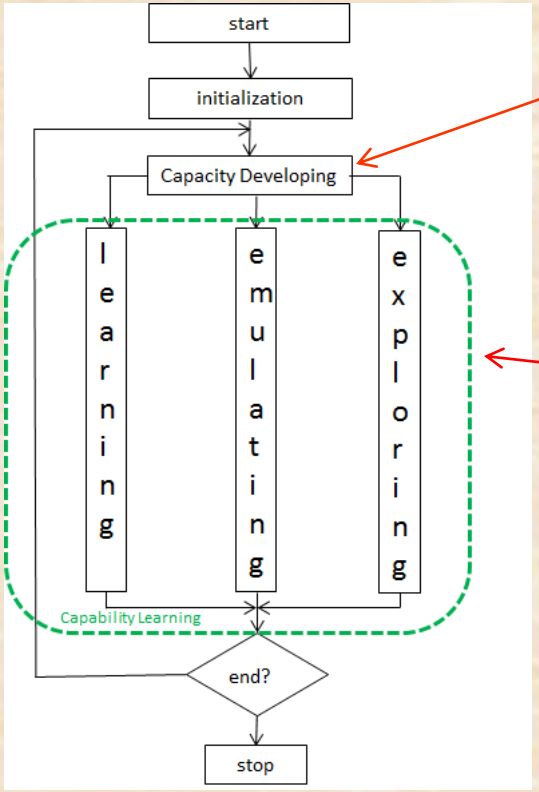

Level selection strategy
Parameter tuning
…

GA
PSO
BSO
…

unified swarm intelligence framework

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Conclusions

1. Developmental learning: capacity developing and capability learning → Developmental swarm intelligence
2. Innovation →Innovation-inspired optimization algorithms
3. Unified swarm intelligence framework

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Thank You !