Diverse environmental conditions accelerate the searching speed of genetic algorithm

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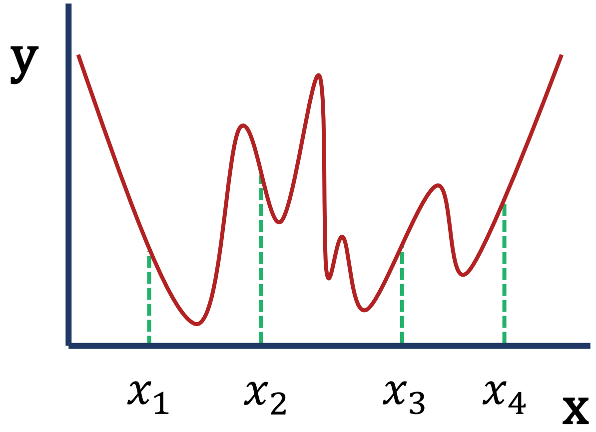
Genetic Algorithm

Example) Finding the minimum point of unknown function

Initialization

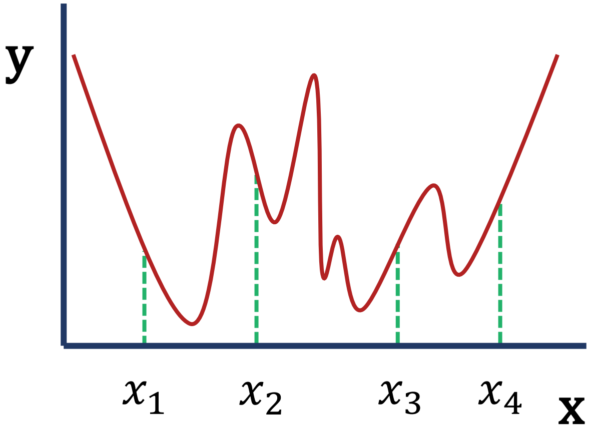


$f(x_1) = 2.5$
$f(x_2) = 4.2$
$f(x_3) = 2.6$
$f(x_4) = 4.1$

Genetic Algorithm

Example) Finding the minimum point of unknown function

Initialization



$$f(x_1) = 2.5$$
$$f(x_2) = 4.2$$
$$f(x_3) = 2.6$$
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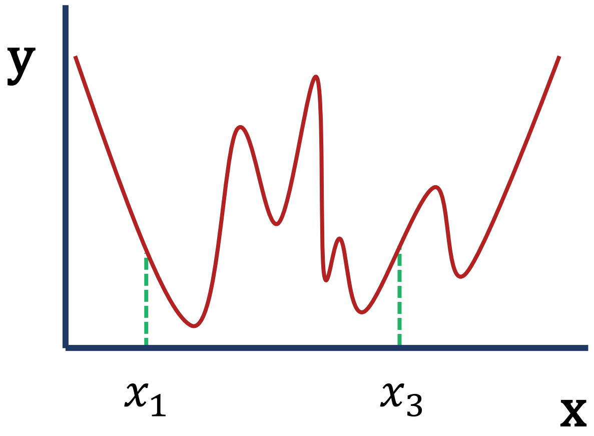
Selection

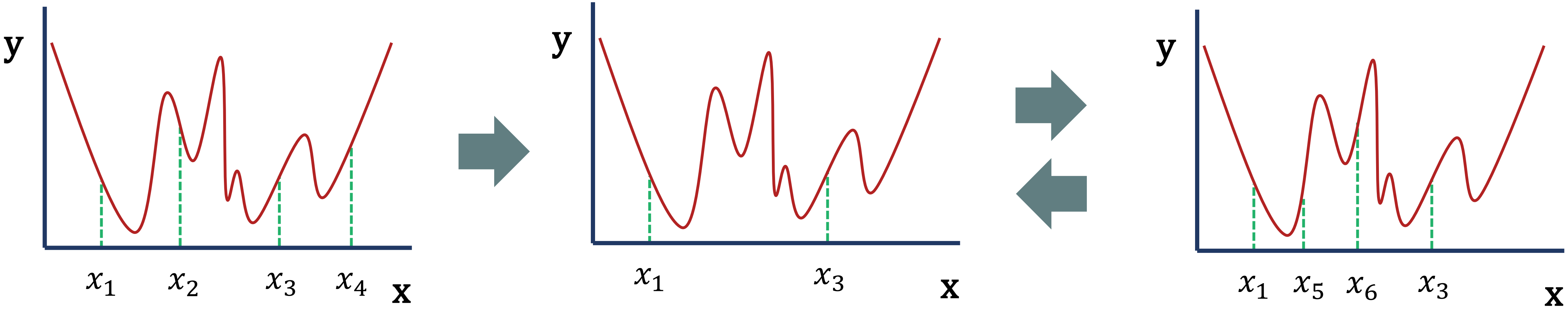


$$f(x_1) = 2.5$$
$$\cancel{f(x_2) = 4.2}$$
$$f(x_3) = 2.6$$
$$\cancel{f(x_4) = 4.1}$$

Genetic Algorithm

Example) Finding the minimum point of unknown function

Initialization | **Selection** | **Reproduction & Mutation**



Initialization:

$f(x_1) = 2.5$
$f(x_2) = 4.2$
$f(x_3) = 2.6$
$f(x_4) = 4.1$

Selection:

$f(x_1) = 2.5$
$\cancel{f(x_2) = 4.2}$
$f(x_3) = 2.6$
$\cancel{f(x_4) = 4.1}$

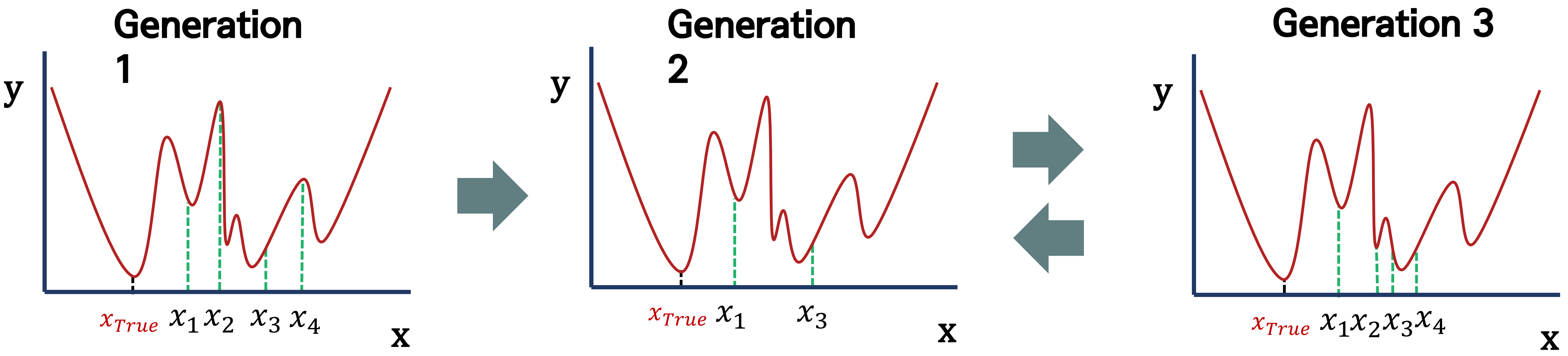
Reproduction & Mutation:

$f(x_1) = 2.5$
$f(x_3) = 2.6$
$f(x_5) = 2.3$
$f(x_6) = 3.3$

Finding optimal solution through natural selection of arbitrary solutions.

Genetic Algorithm

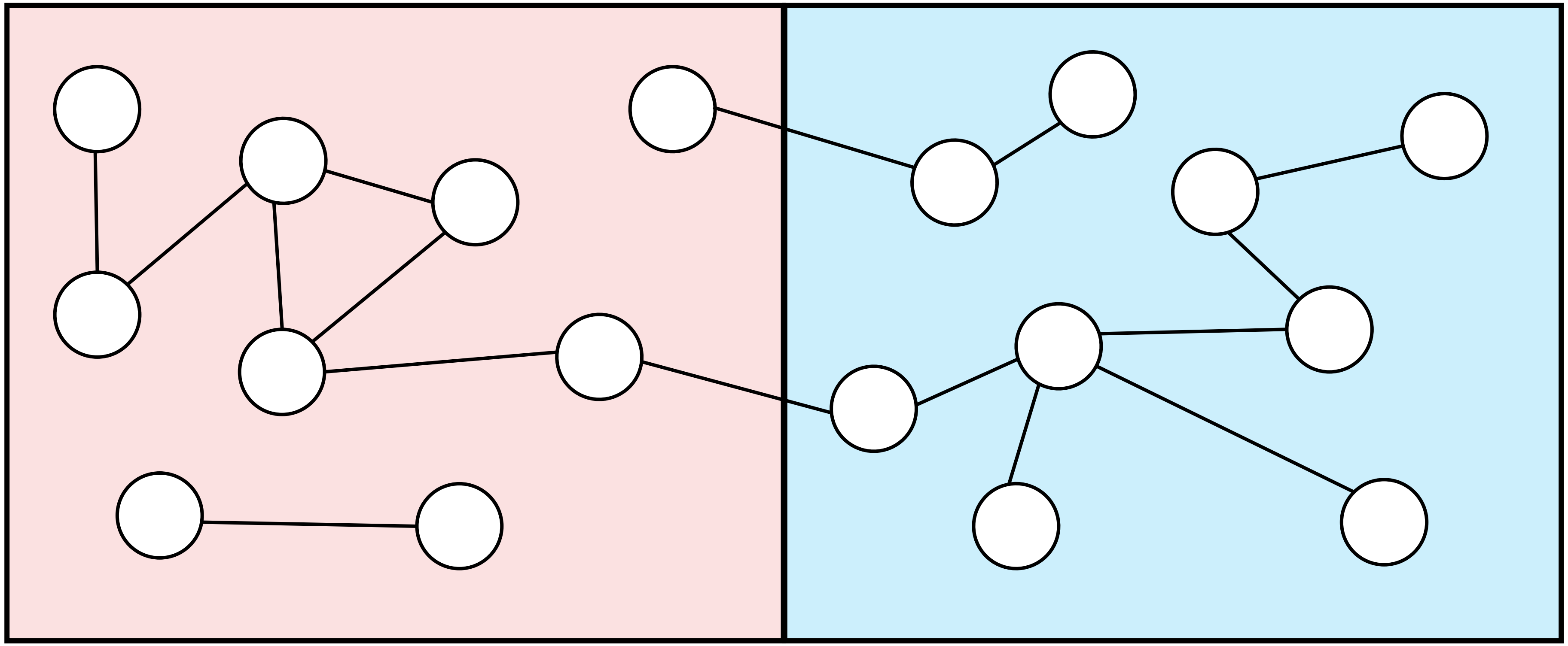
Dilemma of genetic algorithm: efficiency vs diversity



- Purely greedy version of G.A is easy to fall into the local minimum
- Most of diversity-supplying methods hinder the efficiency of system (ex:mutation)
- Two contradicting aspect of G.A

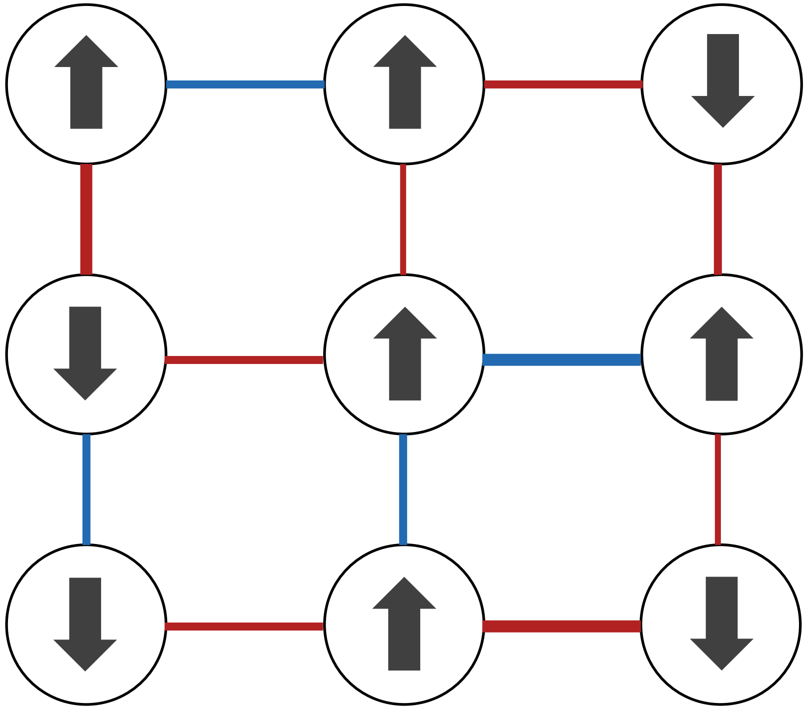
Genetic Algorithm

Adaptation & Interbreeding



- In reality, genetic pool of local community is affected by environmental condition
- How does genetic heterogeneity between parents influence their offsprings?

Spin-glass problem

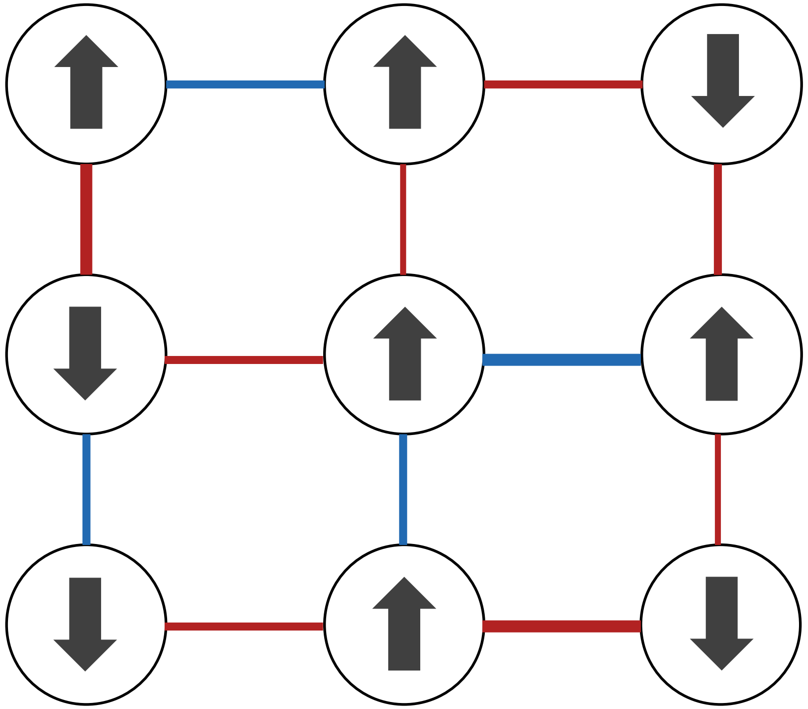


Heterogeneous interaction constant
Between i and j

$$H = -\sum_{\langle ij \rangle} \boxed{J_{ij}} S_i S_j - h \sum_i S_i$$

- Theoretical model for amorphous solid
- $S_i = \pm 1$
- J_{ij} = extracted from $\mathcal{N}(\mu, \sigma)$
- Finding the ground energy of given $\{J_{ij}\}$
- NP-Complete problem for $d \geq 3$

Spin-glass problem

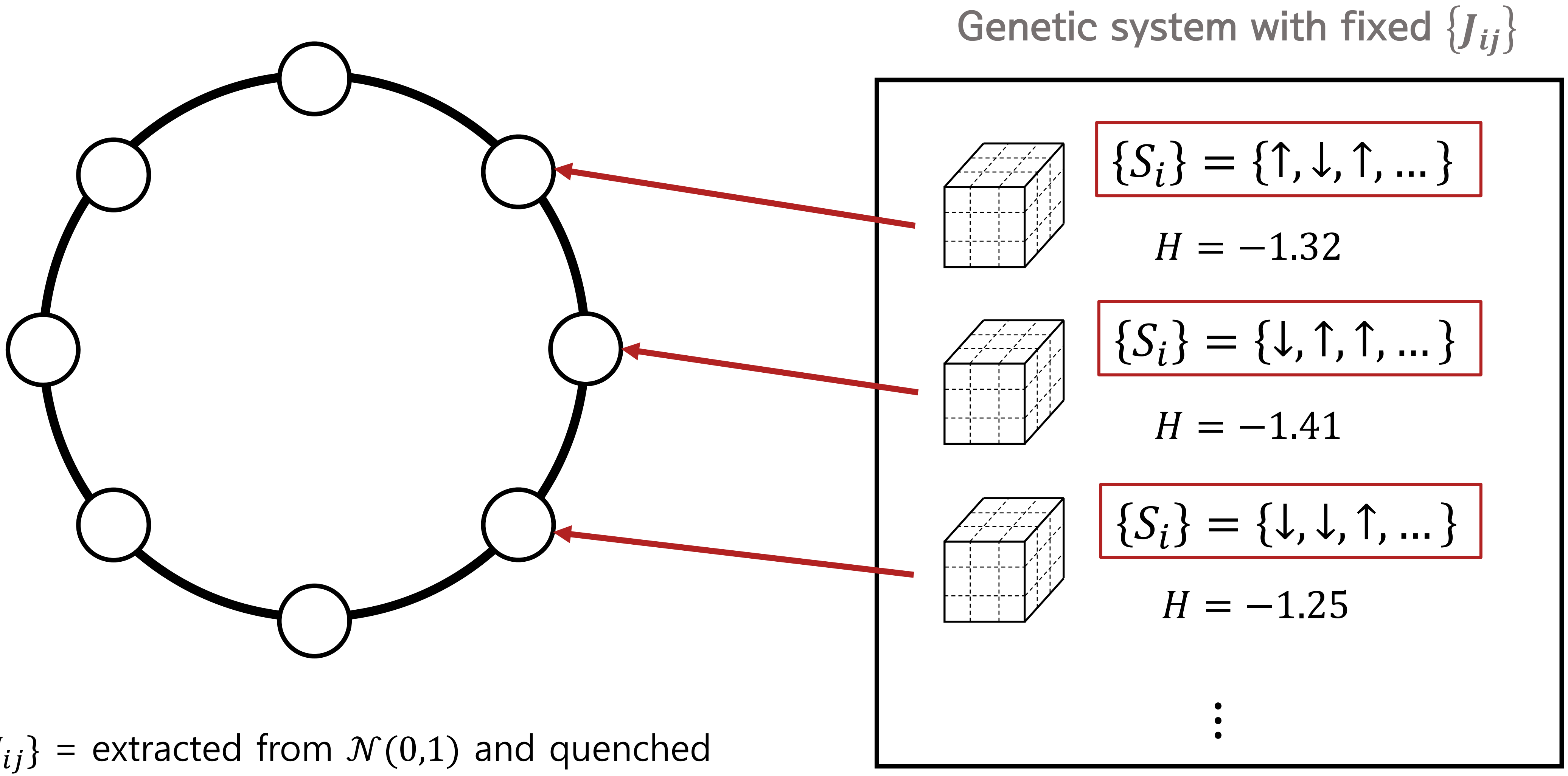


Uniform external field
for entire system

$$H = -\sum_{\langle ij \rangle} J_{ij} S_i S_j - \boxed{h} \sum_i S_i$$

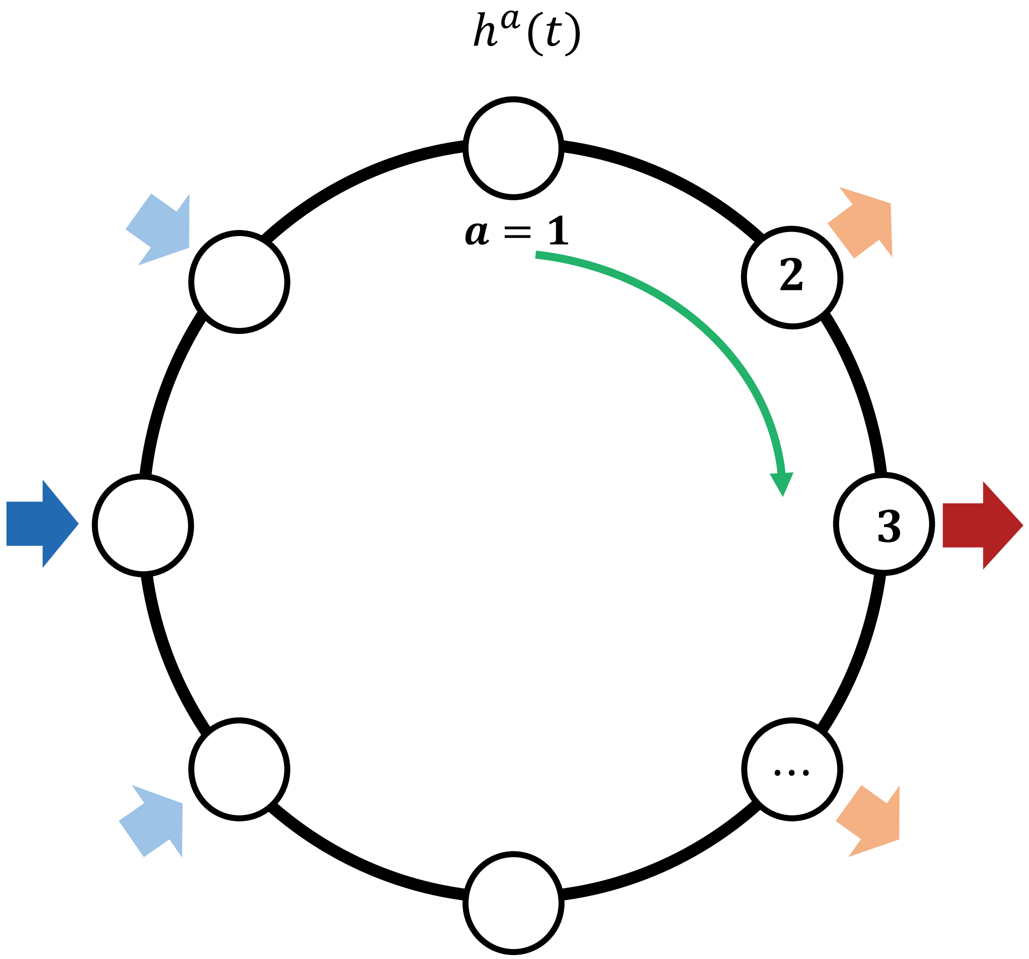
- Theoretical model for amorphous solid
- $S_i = \pm 1$
- J_{ij} = extracted from $\mathcal{N}(\mu, \sigma)$
- Finding the ground energy of given $\{J_{ij}\}$
- NP-Complete problem for $d \geq 3$

Method: initialization



- $\{J_{ij}\}$ = extracted from $\mathcal{N}(0,1)$ and quenched
- Randomly initialized 100 spin configuration (node)
- All the nodes are arranged in ring structure

Method: field variation



Climate at location a

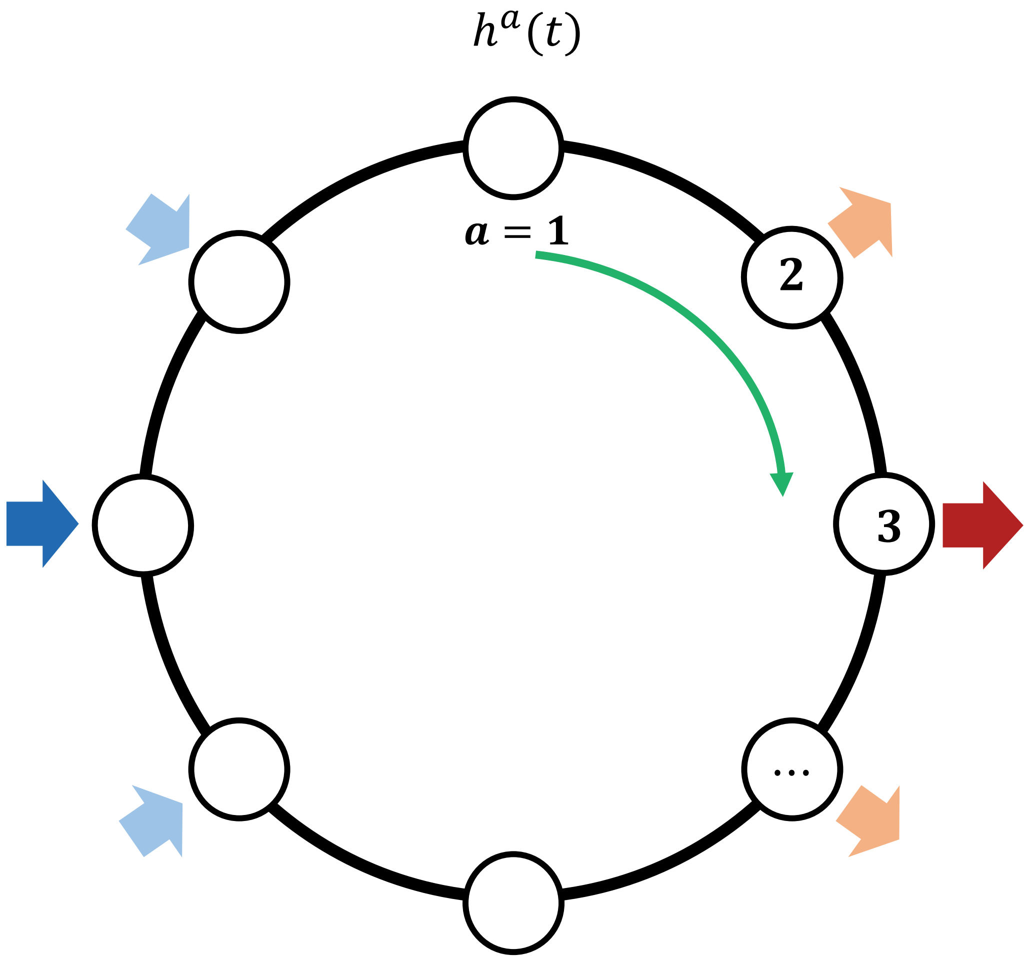
Location (geographic)

$$h^a(t) = h_0 \sin\left(2\pi\left(\frac{a}{N} - \frac{t}{T}\right)\right)$$

Period (climatic)

- Time-varying heterogeneous field on each site
- Wavelength = system size
- Control parameter: h_0, T

Method: field variation



Climate at location a

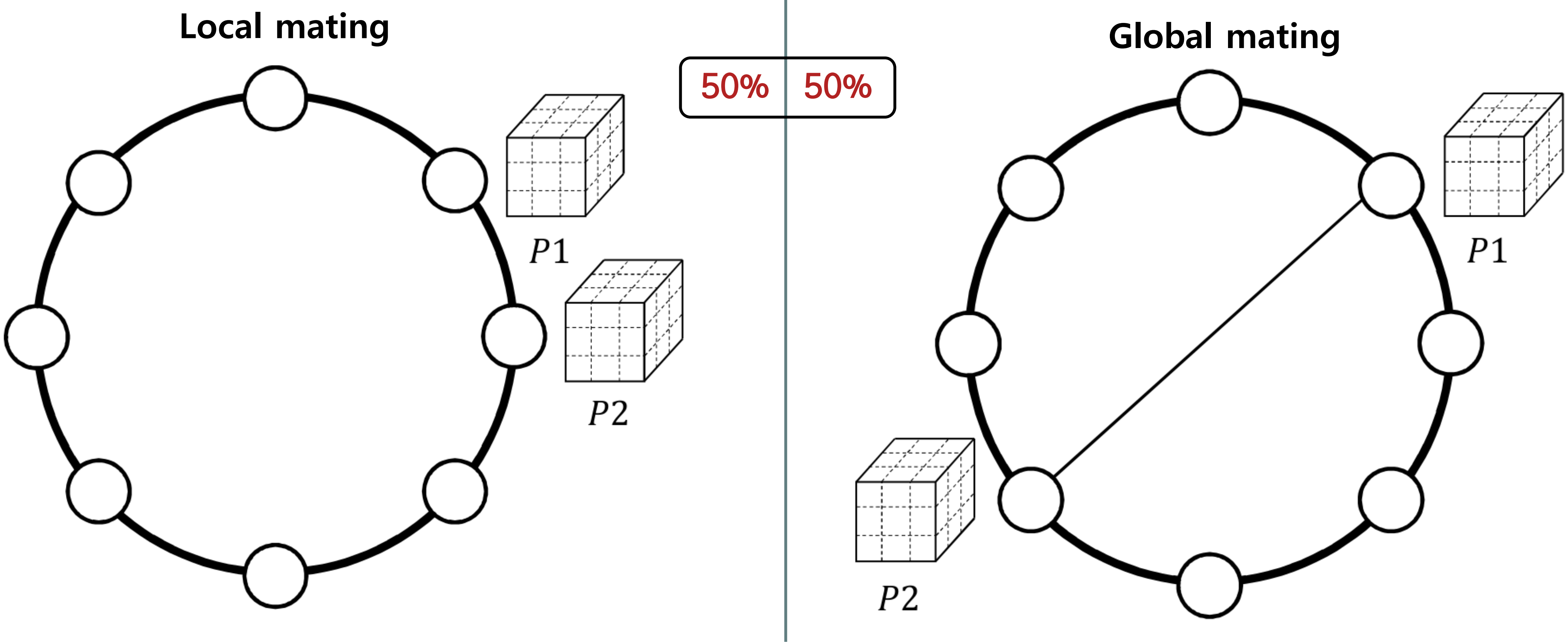
Location (geographic)

$$h^a(t) = \boxed{h_0} \sin\left(2\pi\left(\frac{a}{N} - \frac{t}{\boxed{T}}\right)\right)$$

Period (climatic)

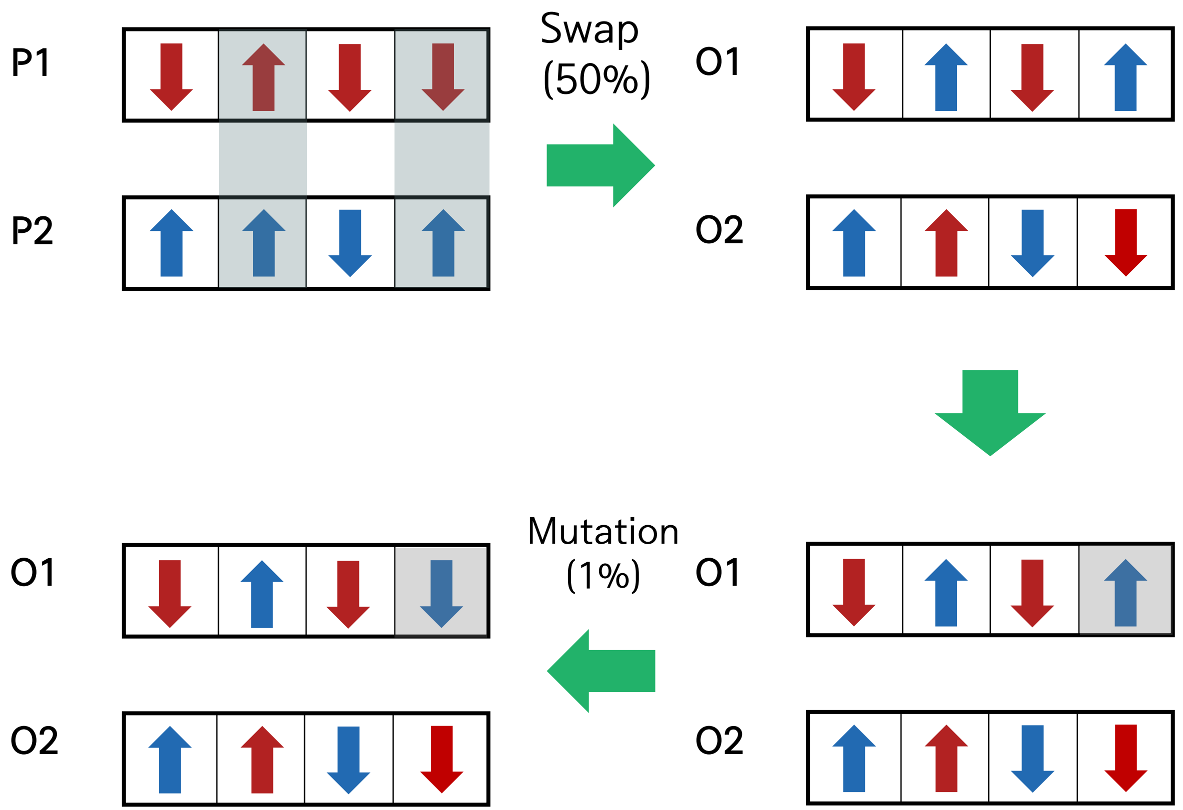
- Time-varying heterogeneous field on each site
- Wavelength = system size
- Control parameter: h_0, T

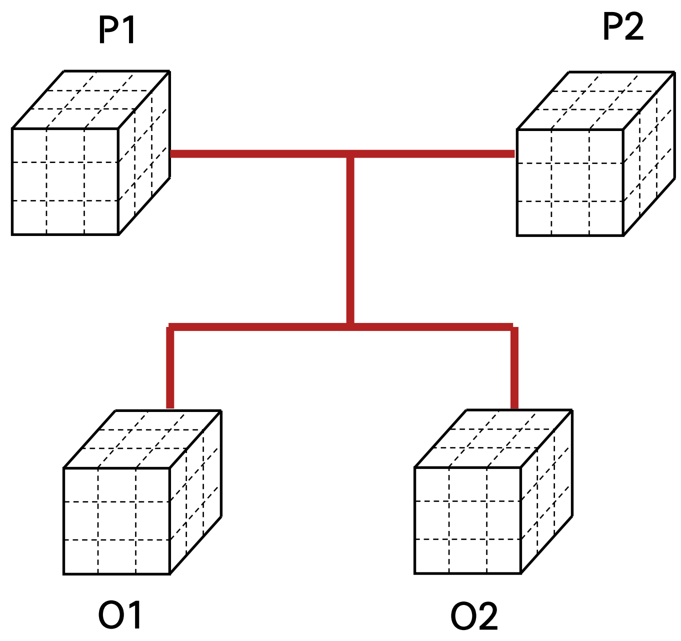
Method: mating



- Select 2 parent nodes in genetic system
- Assign local or global mating with same probability

Method: reproduce

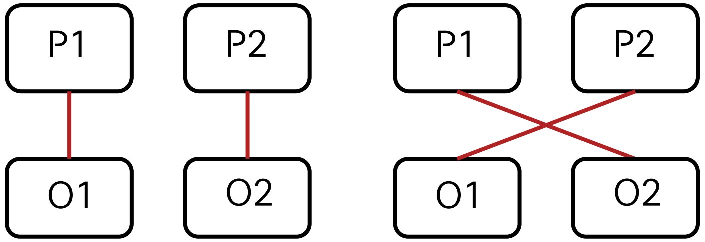




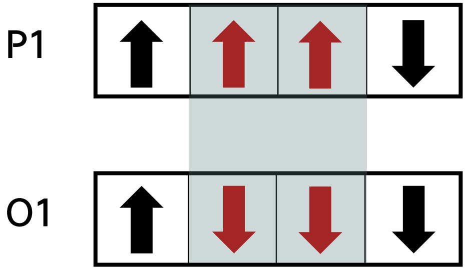
- Each mating pair makes two offspring nodes
- Uniform swapping and 1% mutation rate

Method: selection

Possible competition pairs



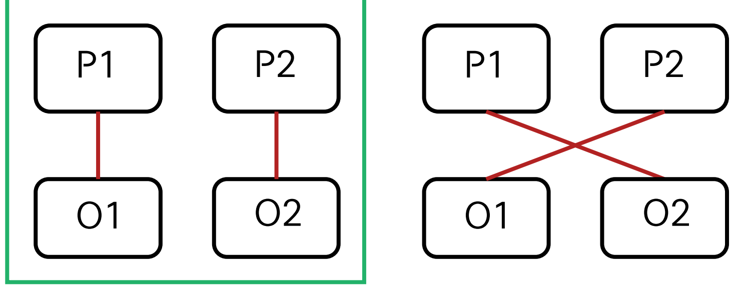
$D(\alpha,\beta)$ = Ratio of different spin between a and b



$$D(P1, C1) = \frac{2}{4} = 0.5$$

Method: selection

Possible competition pairs

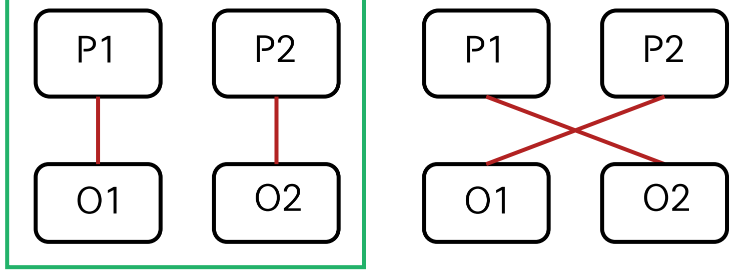


$$if\ D(P1,O1) + D(P2,O2) < D(P1,O2) + D(P2,O1)$$

Each offspring competes with more similar parent

Method: selection

Possible competition pairs

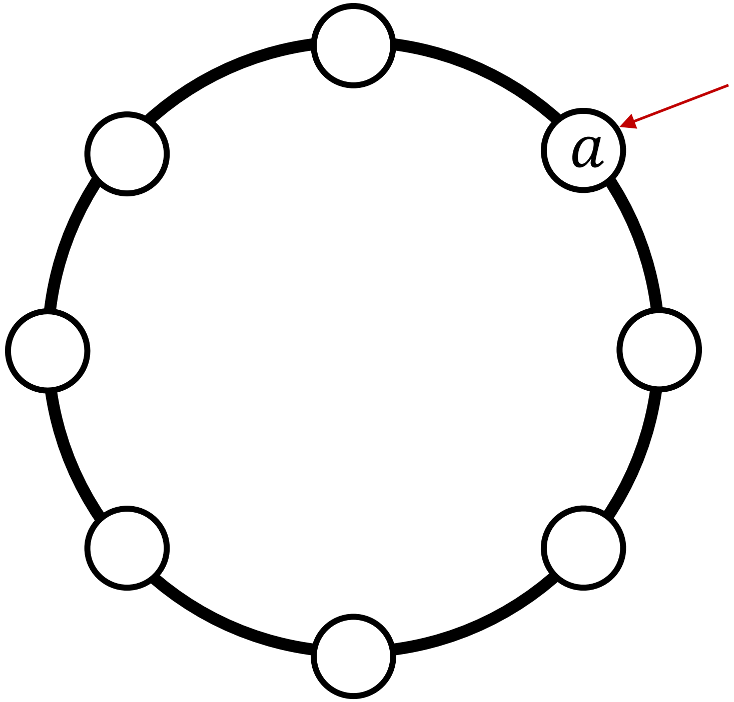


$$if\ D(P1,O1) + D(P2,O2) < D(P1,O2) + D(P2,O1)$$

Each offspring competes with more similar parent

P1 vs O1

$$\underset{P1,O1}{\operatorname{argmin}}\, E^{a}(\{S_i\})$$



$$\left(E_a = -\sum_{\langle ij\rangle} J_{ij}\, S_i S_j - h_a \sum_i S_i\right)$$

Each pair competes for energy in parent’s location

Result

Simulation

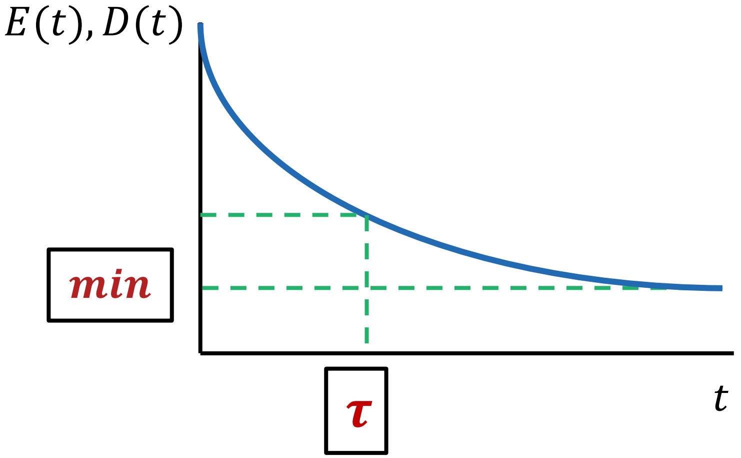
Number of node (N)	100
Number of ensemble	2000
System size (L)	10
Simulation time	1000

- $\{J_{ij}\}$ is initialized in each ensemble
- Unit time $(t) = \frac{N}{2}(50)$ mating processes
- Total number of spin $= L^3 = 1000$

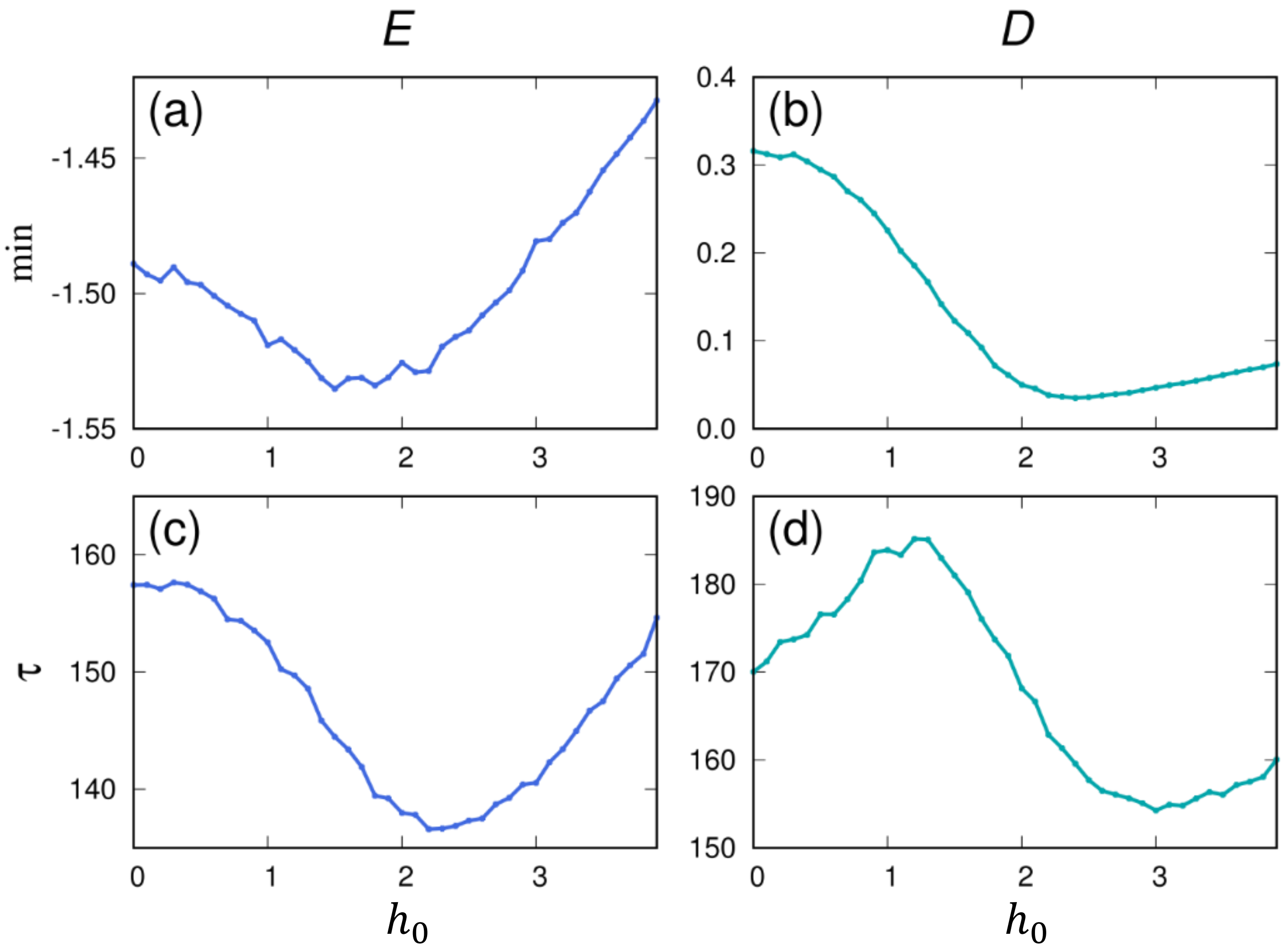
Measurement

$$E_{avg}(t) \equiv -\left\langle \frac{1}{NL^3} \sum_{a} \sum_{\langle ij \rangle} J_{ij} S_i^a S_j^a \right\rangle$$

$$D_{avg}(t) \equiv \left\langle \frac{1}{N(N-1)} \sum_{\alpha \neq \beta} D(a, b) \right\rangle$$

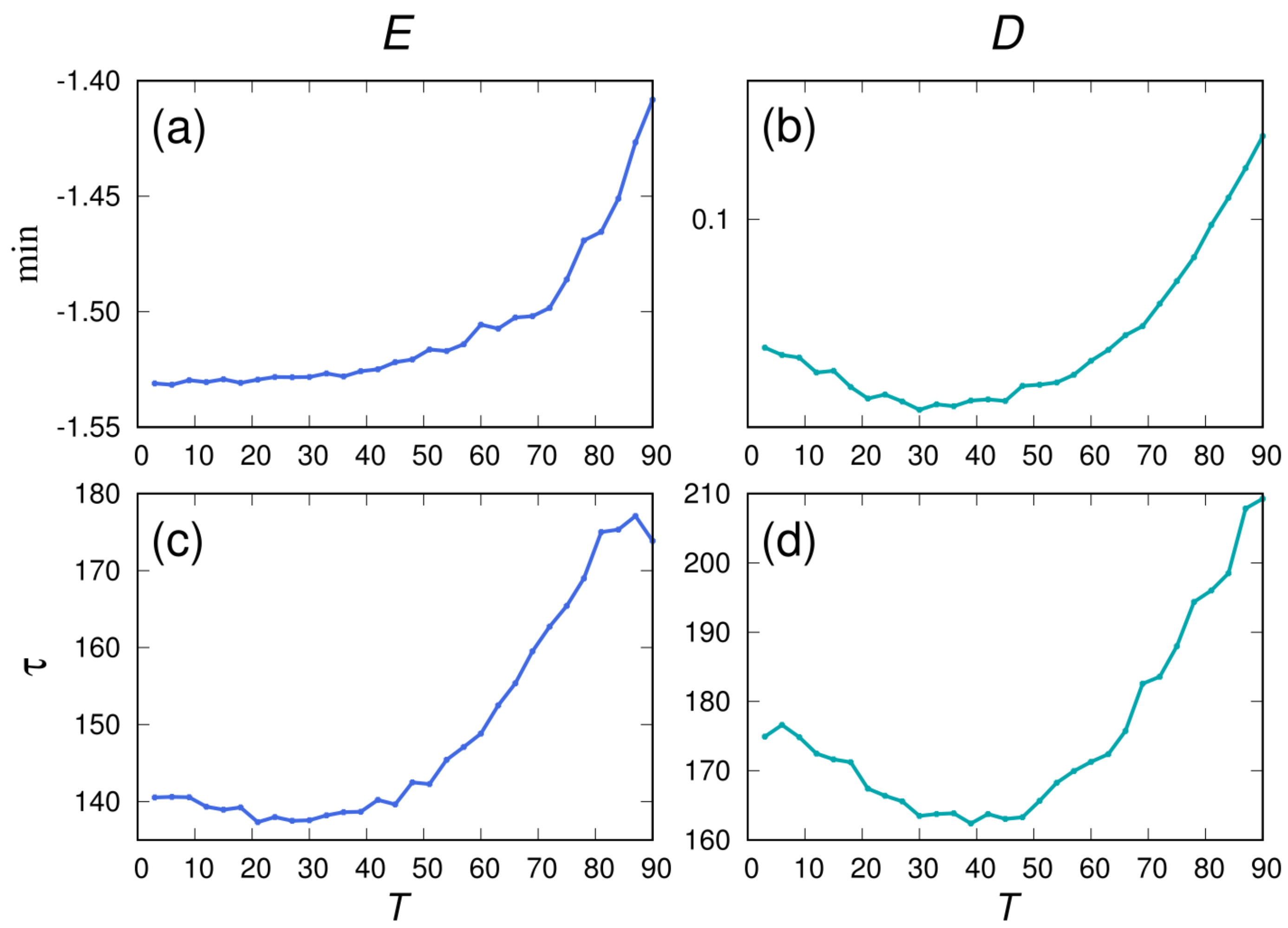


Result



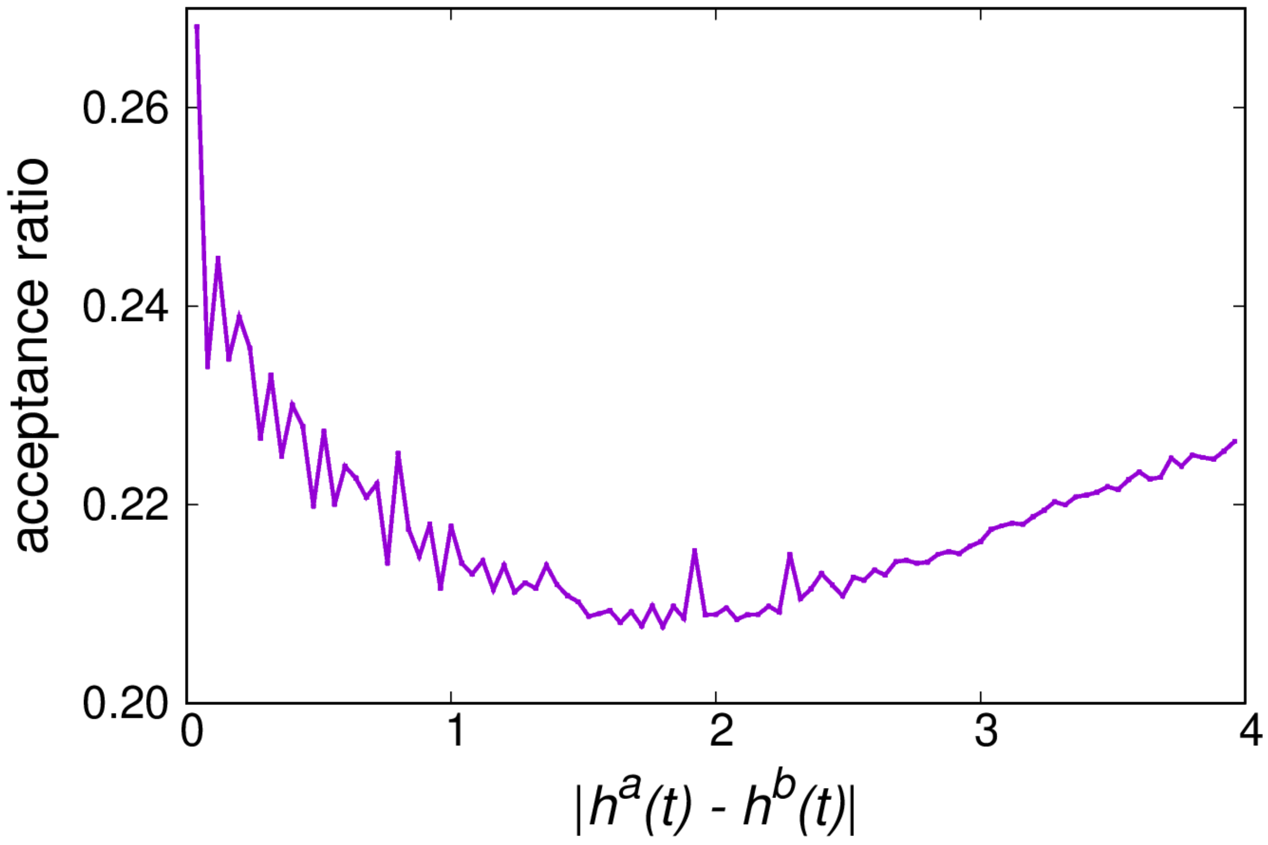
Genetic system exhibits lower energy and diversity at optimal $\boldsymbol{h_0}$

Result

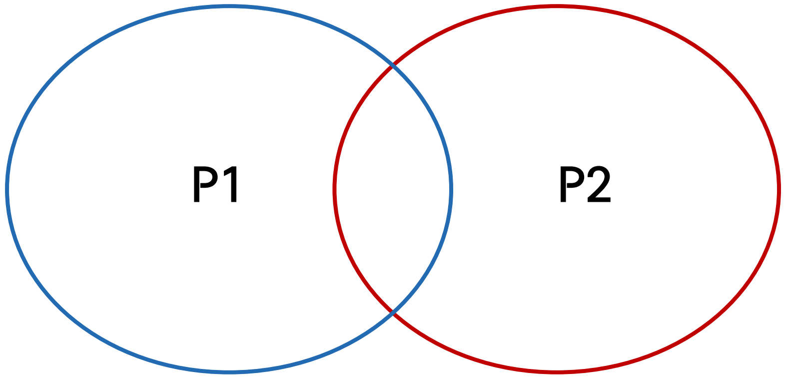


Genetic system exhibits lower energy and diversity at proper T

Result



- Acceptance ratio: $\frac{number\ of\ succeded\ offspring}{total\ number\ of\ offspring}$
- 0.128 for no field condition
- Properly different partnership makes advance
- Effect of basin of attraction?



Summary

Did

- Conceptual extension of genetic algorithm
- Heterogeneous and time-varying external field
- Local and Global mating in ring network structure
- Local competition between parents and offsprings
- Applied to 3-dimensional spin-glass problem

Found

- Proper heterogeneity enhances system efficiency
- Disparate partnership makes advance
- Effect of environmental condition (ex: climate)
- Systemic approach to manage gene pool of system

Deeply grateful for your attention!