Summary of Chapter 5 : Evolutionary Computation

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Outline

1 Overview

2 Biological Inspiration to Search

3 DNA Computing

4 Evolutionary Computation

5 Evolutionary Algorithm
- Genetic Algorithm
- Evolutionary Programming
- Evolutionary Stratrgies

6 Review

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Overview

A new thought of
heuristic search

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Overview

A new thought of heuristic search

- meta-heuristic

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- meta-heuristic
- (stochastic) optimization algorithm

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Overview

A new thought of heuristic search

- meta-heuristic
- (stochastic) optimization algorithm
- population oriented

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Overview

A new thought of heuristic search

- meta-heuristic
- (stochastic) optimization algorithm
- population oriented
- nature based & global search

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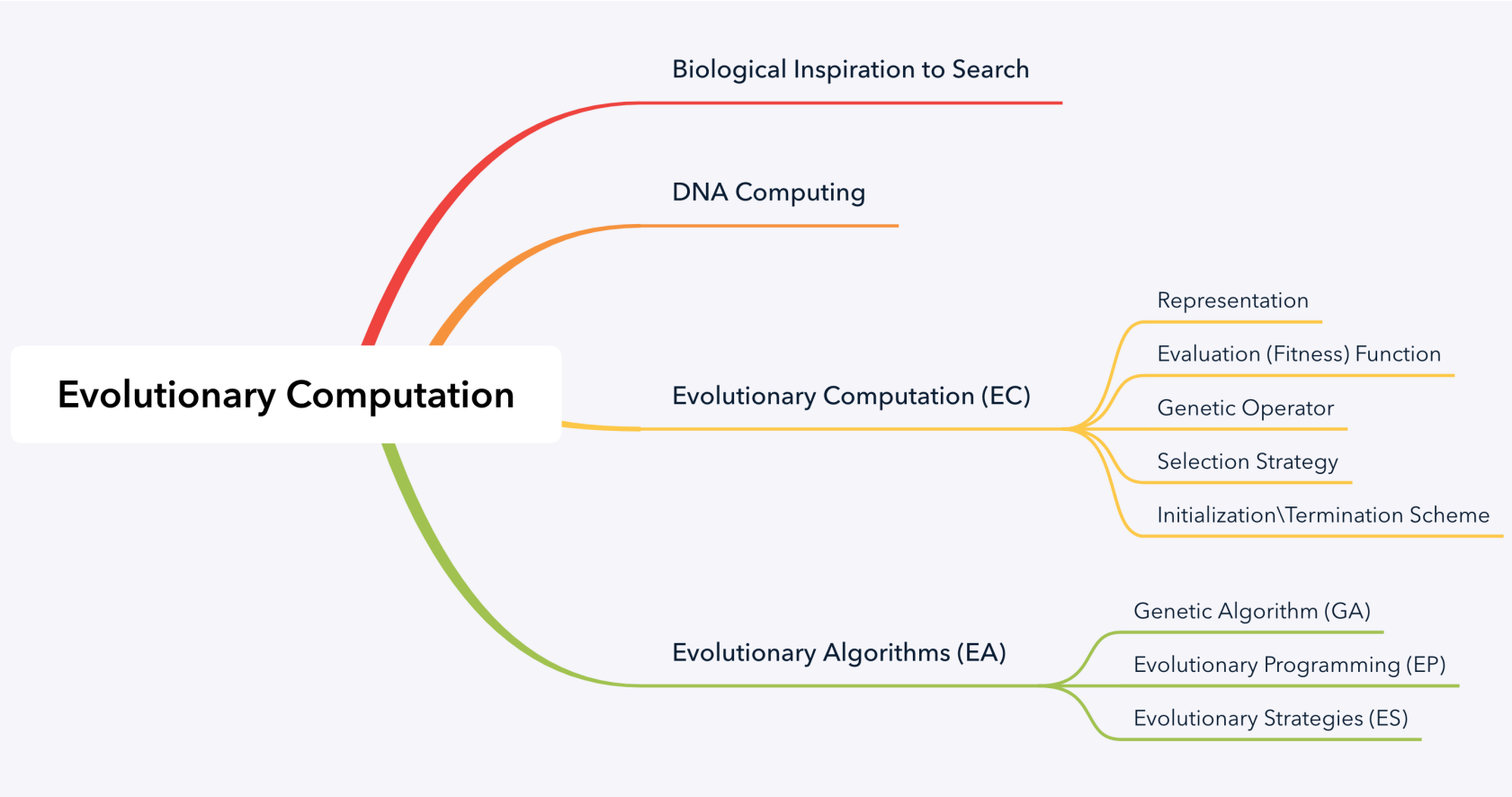
Mind-Map


Evolutionary Computation
Biological Inspiration to Search
DNA Computing
Evolutionary Computation (EC)
Representation
Evaluation (Fitness) Function
Genetic Operator
Selection Strategy
Initialization\Termination Scheme
Evolutionary Algorithms (EA)
Genetic Algorithm (GA)
Evolutionary Programming (EP)
Evolutionary Strategies (ES)

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Question

The best problem solver ?

Question

The best problem solver ?

- The human brain $\rightarrow$ Neural Computation

Question

The best problem solver ?

- The human brain $\rightarrow$ Neural Computation
- The evolution mechanism $\rightarrow$ Evolutionary Computation

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Darwinian Evolution

- population scale
- competition
- fitness
- selection
- diversity
- chance

Evolution Theory

Base Elements :

Evolution Theory

Base Elements :

- DNA

Evolution Theory

Base Elements :

- DNA
- Genotype & Phenotype

Evolution Theory

Base Elements :

- DNA
- Genotype & Phenotype
- Mutation & Recombination

Evolution Theory

Base Elements :

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Process :

Mutation & Recombination
$\Rightarrow$ Competition
$\Rightarrow$ Reproduction
$\Rightarrow$ Imporved Genes
$\Rightarrow$ Better Organisms

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DNA Memory

- Four types of units : (A, T, C, G)

DNA Memory

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- Complementary units : (A−T, C−G)

DNA Memory

- Four types of units : (A, T, C, G)
- Complementary units : (A−T, C−G)
- Double-stranded strings

Uniqueness of DNA

- Extremely dense information storage

Uniqueness of DNA

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- Enormous parallelism

Uniqueness of DNA

- Extremely dense information storage
- Enormous parallelism
- Extraordinary energy efficiency

Application—Adleman's Experiment (TSP)

i Encode : vertex molecules & edge molecules

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i Encode : vertex molecules & edge molecules

ii Merge vertex molecules and edge molecules

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Application—Adleman's Experiment (TSP)

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iii Melting

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Application—Adleman's Experiment (TSP)

i Encode : vertex molecules & edge molecules

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iv Annealing

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Application—Adleman's Experiment (TSP)

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Application—Adleman's Experiment (TSP)

i Encode : vertex molecules & edge molecules
ii Merge vertex molecules and edge molecules
iii Melting
iv Annealing
v Merging
vi Amplification

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Application—Adleman's Experiment (TSP)

i. Encode : vertex molecules & edge molecules
ii. Merge vertex molecules and edge molecules
iii. Melting
iv. Annealing
v. Merging
vi. Amplification
vii. Selection

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Evolution vs. Search

Evolution	vs.	Search
Environment	$\Longleftrightarrow$	Problem
Individual	$\Longleftrightarrow$	Candidate Solution
Fitness	$\Longleftrightarrow$	Quality

Evolution Mechanism

- Ingredients

Evolution Mechanism

- Ingredients
- Diversity $\rightarrow$ increasing by
  genetic operators;
  decreasing by selection

Evolution Mechanism

- Ingredients
- Diversity $\rightarrow$ increasing by genetic operators; decreasing by selection
- Evolution Cycle $\Longrightarrow$

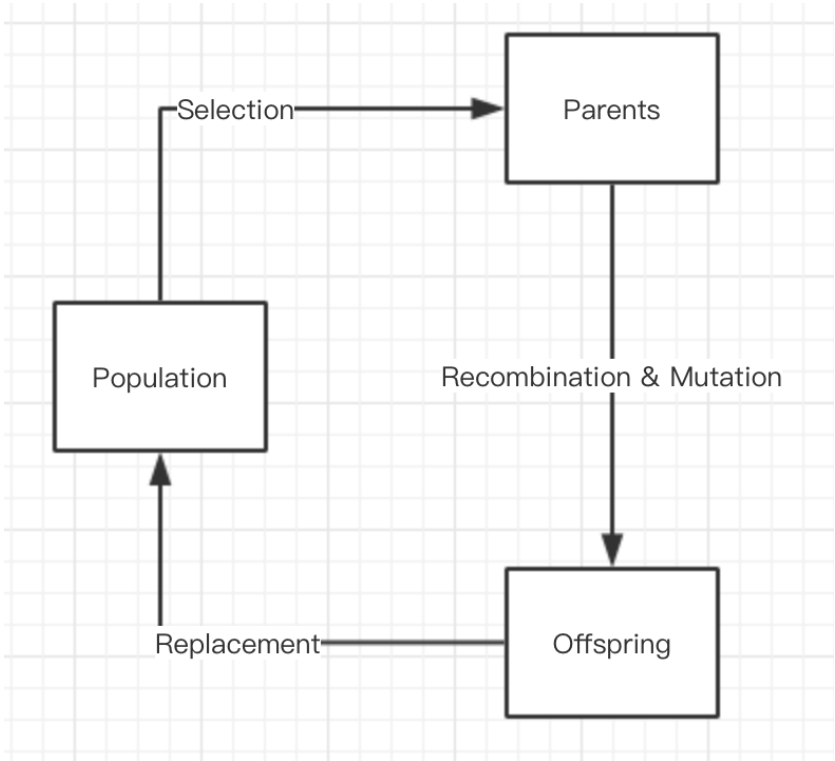

Figure: Evolution Cycle

Five factors

- ★ Representation
- ★ Fitness Evaluation
- ★ Genetic Operations
- ★ Selection Strategies
- ★ Initialization/Termination Schemes

Five factors

- ★ Representation
  - ▶ Genotypic
  - ▶ Phenotypic
- ★ Fitness Evaluation
- ★ Genetic Operations
- ★ Selection Strategies
- ★ Initialization/Termination Schemes

- Genotypic : genotype ⇔ phenotype (one to one?)
- Phenotypic : problem-specific encodings

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Five factors

- ★ Representation
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- quality function or objective function
- a single real-valued fitness for each phenotype

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Five factors

- ★ Representation
- ★ Fitness Evaluation
- ★ Genetic Operations
  - ▶ Mutation
  - ▶ Recombination
- ★ Selection Strategies
- ★ Initialization/Termination Schemes

- generate new candidate solutions
-
  - $N_p = 1$: mutation
  - $N_p > 1$: recombination
  - $N_p = 2$: crossover

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Five factors

- ★ Representation
- ★ Fitness Evaluation
- ★ Genetic Operations
- ★ Selection Strategies
  - ▶ Parent Selection
  - ▶ Survivor Selection
- ★ Initialization/Termination Schemes

- Parent Selection :
  fitness based probability (stochastic nature) ⇒ escape from local optima
- Survivor Selection :
  Fitness based || Age based

Five factors

- ★ Representation
- ★ Fitness Evaluation
- ★ Genetic Operations
- ★ Selection Strategies
- ★ Initialization/Termination Schemes

Balance between selection and genetic operation

- Selection: exploitation ⇒ reduce scope of search
- Genetic Operation: exploration ⇒ expand scope of search

Five factors

- ★ Representation
- ★ Fitness Evaluation
- ★ Genetic Operations
- ★ Selection Strategies
- ★ Initialization/Termination Schemes

- Initialisation : random
- Termination : condition
  checked every generation

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Application : 8 Queens Problem

Representation	Permutation
Recombination	"Cut-and-crossfill" crossover
Recombination probability	100%
Mutation	Swap
Mutation probability	80%
Parent selection	Best 2 out of random 5
Survival seletcion	Replace worst
Population size	100
Number of offspring	2
Initialisation	Random
Termination condition	Solution or 10000 fitness evalution

Advantages & Disadvantages

Advantages :

- Widely applicable
- No priori assumption
- Insensitive to noise
- Easy to parallelize

Advantages & Disadvantages

Advantages :

- Widely applicable
- No priori assumption
- Insensitive to noise
- Easy to parallelize

Disadvantages :

- No guarantee for optimal solution within finite time
- Weak theoretical basis
- Parameter tuning needed

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Genetic Algorithm

- Representation : genome
  - Fixed length Bitstring || Real-valued genome

Genetic Algorithm

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- Operation
  - mutation : mutation rate p_m
  - crossover : p_c

Genetic Algorithm

- Representation : genome
  - Fixed length Bitstring || Real-valued genome
- Operation
  - mutation : mutation rate p_m
  - crossover : p_c
- Selection
  - Greedy
  - Probabilistic $\Rightarrow$ roulette wheel technique

$$Pr(h_i) = \frac{Fitness(h_i)}{\sum_{j=1}^{p} Fitness(h_j)}$$

Evolutionary Programming

- Representation
  - Object variable & Mutation step size :
    $< x_1, \ldots, x_n, \sigma_1, \ldots, \sigma_n >$

Evolutionary Programming

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- Operation
  - mutation : $\begin{cases} x_i' = & x_i + \sqrt{\sigma_i} \cdot N_i(0,1) \\ \sigma_i' = & \sigma_i + \sqrt{\eta \cdot \sigma_i} \cdot N_i(0,1) \end{cases}$
  - recombination : none $\Leftarrow$ one species for each point

Evolutionary Programming

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  - recombination : none $\Leftarrow$ one species for each point
- Selection
  - Parent : one child for each individual
  - Survivor : pairwise competitions in round-robin format

Evolutionary Stratrgies

- Representation
  - Object variable & Mutation step size & Rotation angle :
    $< x_1, \ldots, x_n, \sigma_1, \ldots, \sigma_n, \alpha_1, \ldots, \alpha_k >$

Evolutionary Stratrgies

- Representation
  - Object variable & Mutation step size & Rotation angle :
    $< x_1, \ldots, x_n, \sigma_1, \ldots, \sigma_n, \alpha_1, \ldots, \alpha_k >$
- Operation
  - mutation : adding random noise
    $$\begin{cases} \sigma_i^{'} = & \sigma_i \cdot exp(\tau^{'} \cdot N(0,1) + \tau \cdot N_i(0,1)) \\ \alpha_{ij}^{'} = & \alpha_{ij} + \beta \cdot N_j(0,1) \\ x_i^{'} = & x_i + z_i \end{cases}$$
  - recombination : ...

Evolutionary Stratrgies

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  - recombination : ...
- Selection
  - Parent : uniform random distribution
  - Survivor : $(\mu, \lambda) - selection \mid\mid (\mu + \lambda) - selection$

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Summary

	GA	EP	ES	GP
Representation	Genotype	Phenotype	Phenotype	Genotype
Mutation	✓	✓	✓	✓
Recombination	✓	×	✓	✓
Parent Selection	Probabilistic	Deterministic	Probabilistic	Probabilistic
Survivor Selection	Extinctive, Deterministic	Combined, Probabilistic	Combined, Deterministic	Extinctive, Deterministic

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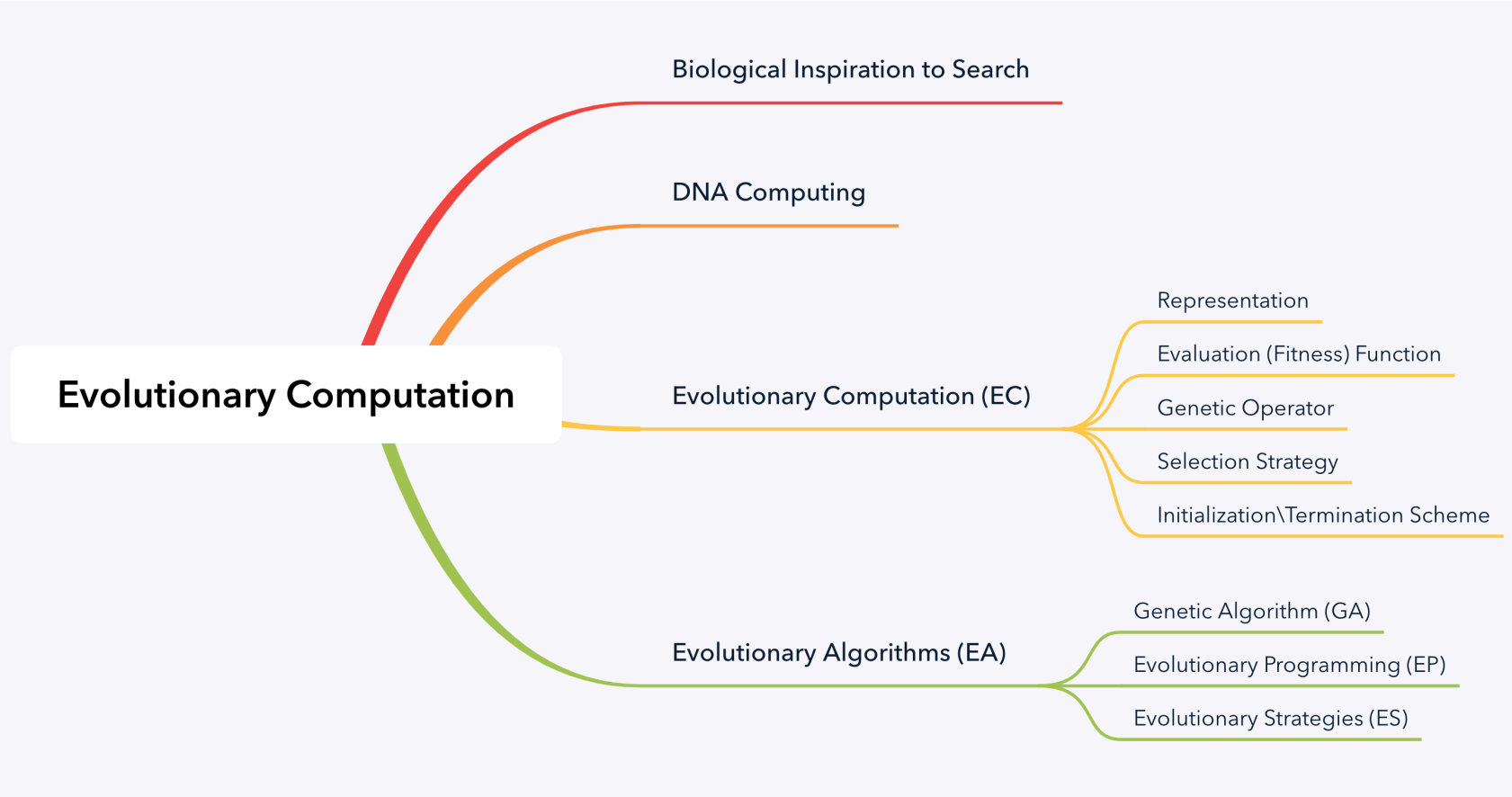
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Thank you

Thank you for listening!