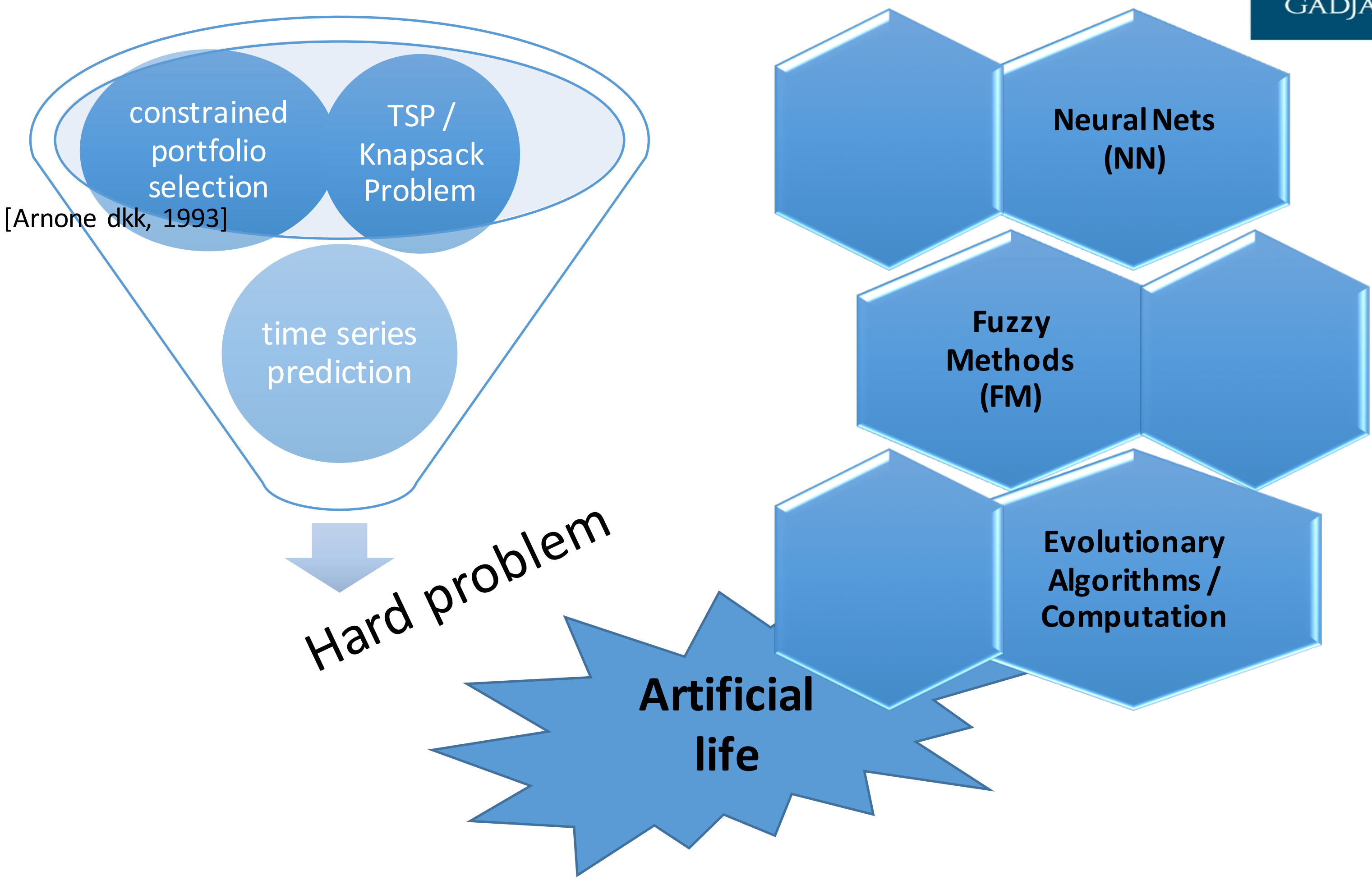
UNIVERSITAS GADJAH MADA

Evolutionary Computation and Its Application

Aina Musdholofah, S.Kom., M.Kom., Ph.D.

Webinar Series Lab SC
Thursday, 30 July 2020

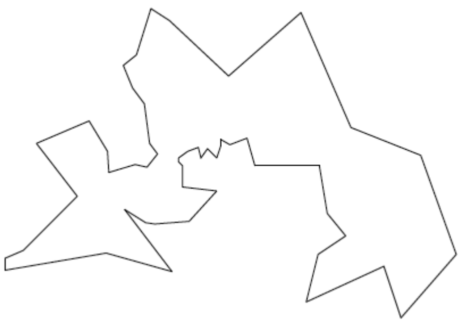
Background


constrained portfolio selection
TSP / Knapsack Problem
[Arnone dkk, 1993]
time series prediction
Hard problem
Artificial life
Neural Nets (NN)
Fuzzy Methods (FM)
Evolutionary Algorithms / Computation

UNIVERSITAS GADJAH MADA

Traveling Salesman Problem (TSP)

- The most popular combinatorial optimization problem
- It can be formulated as follows: given *n* cities and a distance matrix $d_{n,n}$, where each element d_{ij} represents the distance between the cities *i* and *j*, find a tour that minimizes the total distance.
- A tour visits each city exactly once (Hamiltonian cycle).
- The size of the search space is *n*!



TSP instance with 52 cities.

Number of Cities *n*	Size of the Search Space
5	120
10	3,628,800
75	2.5 x 10109

TSP instance with 24,978 cities.

Background (cont.)

Keunggulan Evolutionary Computation:

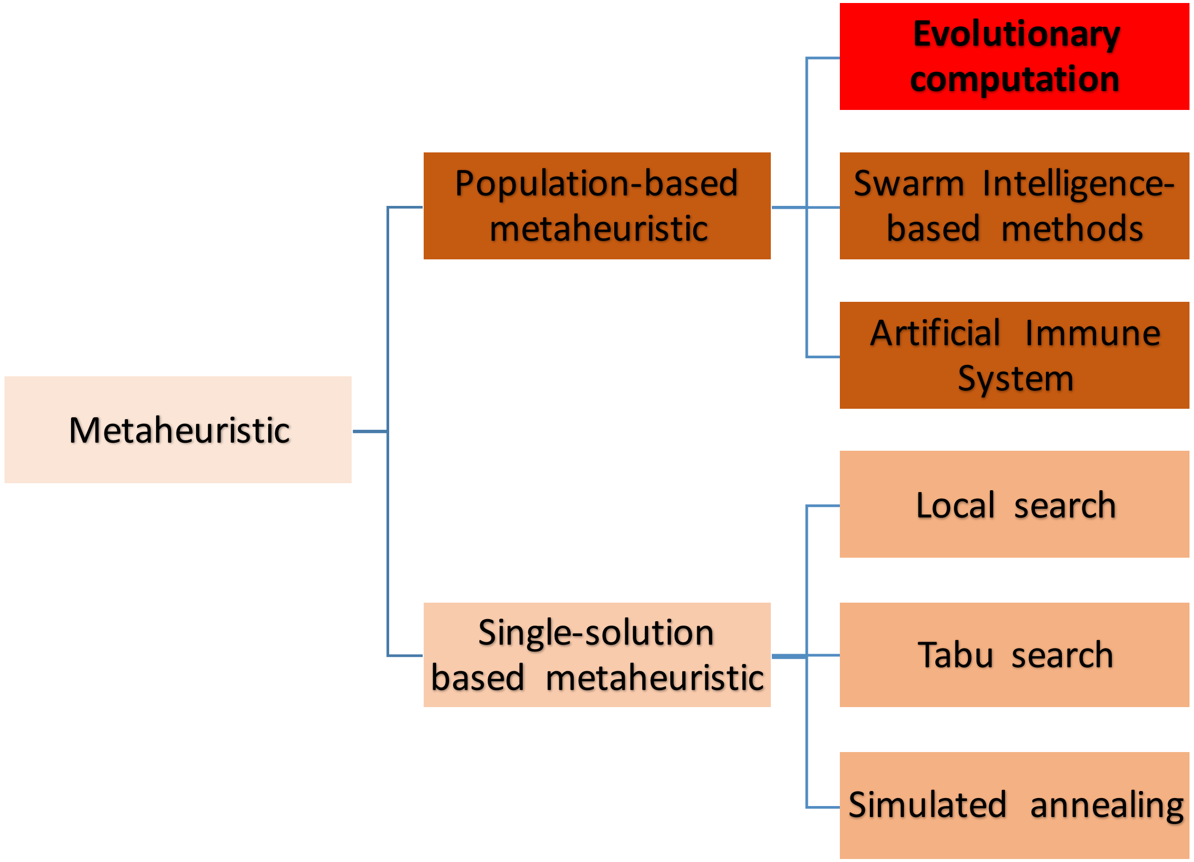
- Payoff-driven.
  - Payoff dapat berarti peningkatan kualitas prediksi atau pengembalian atas tolok ukur dan payoff tersebut dapat dengan mudah diterjemahkan ke fungsi kebugaran untuk EA.
- inherently quantitative,
  - sangat cocok untuk optimasi parameter.
- allow a wide variety of extensions and constraints
  - Metode EC memungkinkan beragam ekstensi dan constraint yang tidak dapat disediakan oleh metode tradisional.
- easily combined with other optimization techniques
  - Metode EC mudah dikombinasikan dengan teknik optimasi lainnya
- extended to Multiobjective optimisation

What is Evolutionary Computation

UNIVERSITAS GADJAH MADA

- evolutionary system as computational process
- for solving complex problem
- model of natural evolutionary system
- artificial life as new artificial evolutionary world
- population-based metaheuristic

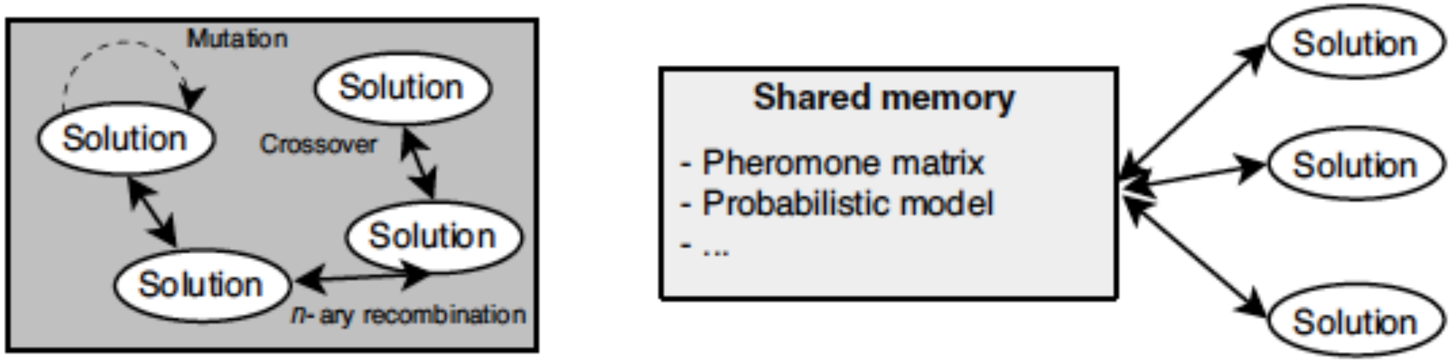
Evolutionary Computation as Metaheuristic Methods



Search Memories of
Population-based Metaheuristic Methods

Metaheuristic Methods	Search Memory
Evolutionary Computation	Population of individuals
Ant colonies	Pheromone matrix
Particle Swarm Optimization	Population of particles
Artificial Bee Colony	Population of bee
Artificial Immune System	Population of antibodies

New Population Generation of
Population-based Metaheuristic Methods



(a) Evolutionary-based P-metaheuristics: evolutionary algorithms, scatter search, ...

(b) Blackboard-based P-metaheuristics: ant colonies, estimation distribution algorithms, ...

Evolution Process Vs Evolutionary Computation

UNIVERSITAS GADJAH MADA

Evolution Process	Evolutionary Computation
Evolution	Problem solving
Individu / Phenotype	Solution / Decoded Solution
Fitness	Objective function
Environment	Optimization problem
Locus	Element of the solution (position)
Allele	Posible value of the element (locus)

Basic of Evolutionary Computation

initialize random population $A(s = o)$

repeat

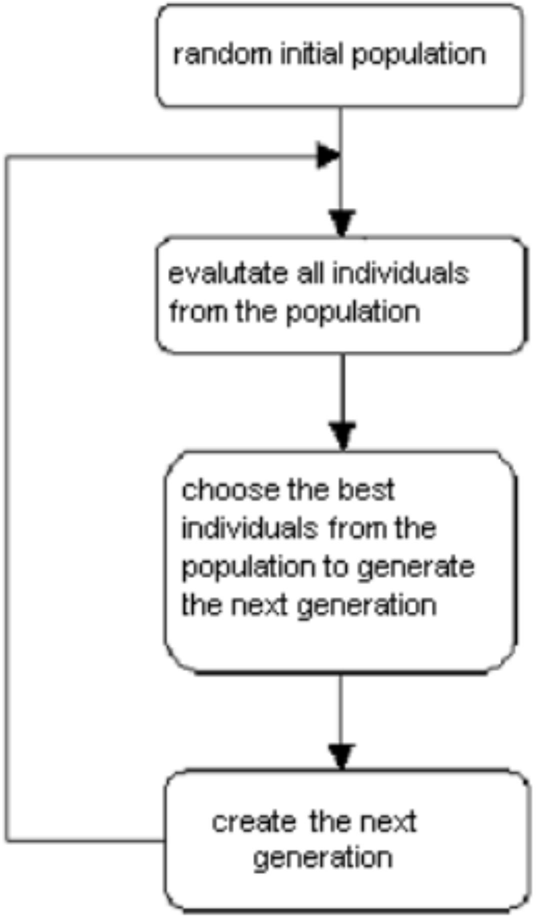
evaluate fitness of all a_i from $A(s)$

select the fittest a_i as parents $B(s)$ from $A(s)$

reproduce descendants $C(s)$ from $B(s)$

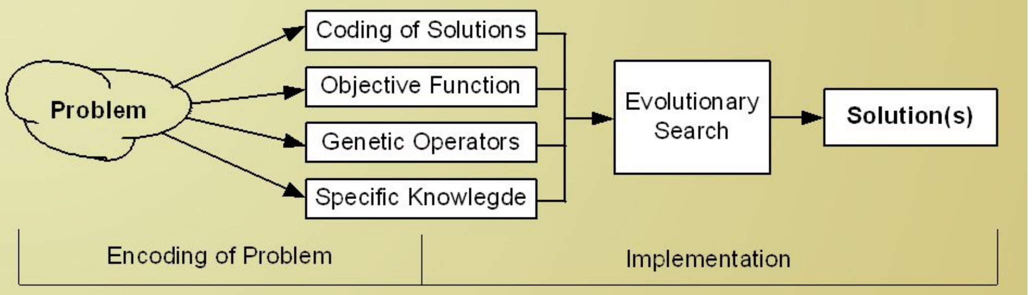
$A(s + 1) = C(s)$

until break criteria is met



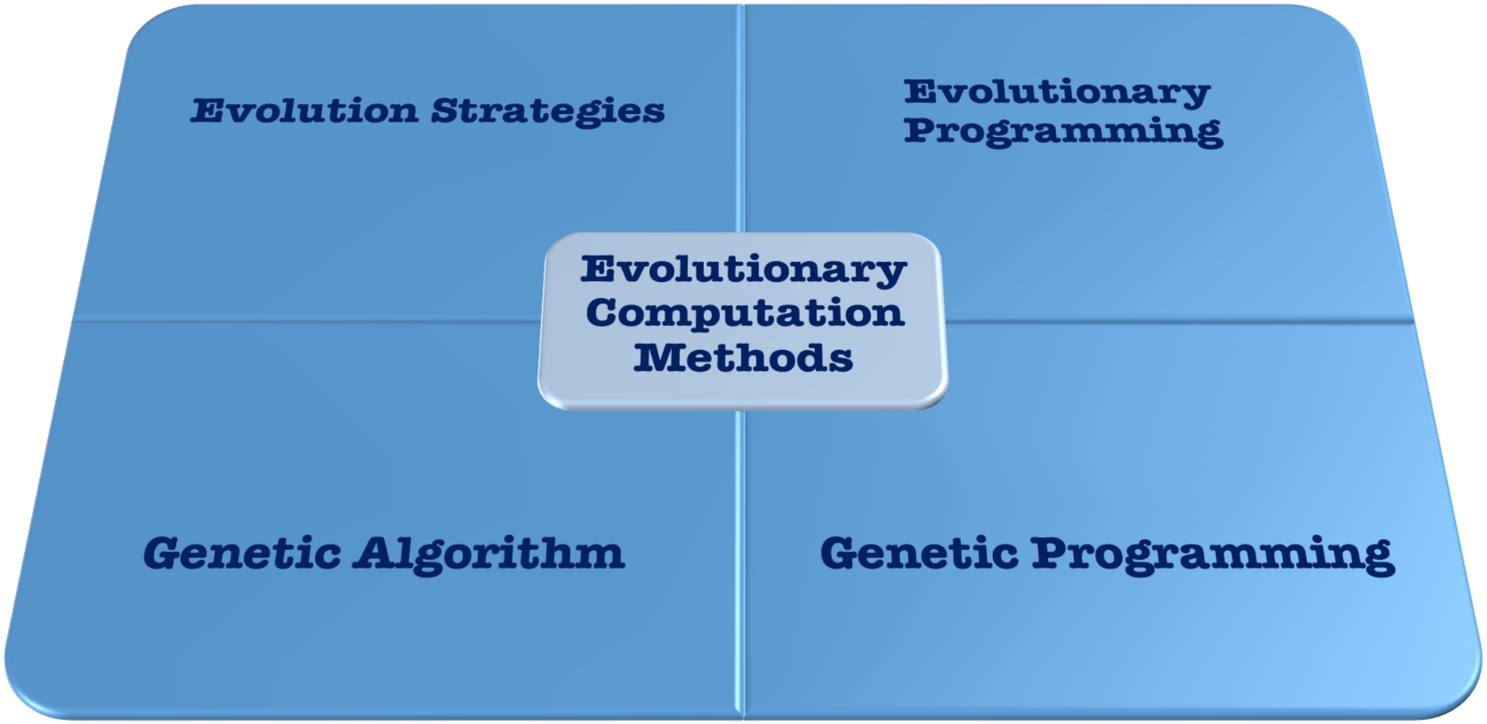
Components of Evolutionary Computation

EA Components



- Representation mechanism (definition of individuals)
- Evaluation function (or fitness function)
- Population as container data structure
- Parent/Survivor selection mechanism
- Variation operators (Recombination, Mutation)
- Initialization procedure / Termination condition

UNIVERSITAS
GADJAH MADA



Comparison 4 EC methods

- Genetic Algorithm (GA)
  - Complete natural process of evolution
  - Various coding of attributes (into set of genes)
- Genetic Programming (GP)
  - Similar to GA
  - Specialized on representing programs or instruction sets as attributes.
- Evolutionary Strategies (ES)
  - Actual expression of an attribute (real numbers)
  - Use of specialized mutation operators
- Evolutionary Programming (EP)
  - Similar to ES
  - No restrictions regarding the data types of attributes
  - Focused on the level of whole species not on single individuals.

	GA	GP	ES	EP
Developers	J. Holland	J. Koza	I. Rechenberg, H.-P. Schwefel	D. Fogel
Original applications	Discrete optimization	Machine learning	Continuous optimization	Machine learning
Attribute features	Not too fast	Slow	Continuous optimization	-
Special features	Crossover, many variants	-	Fast, much theory	No recombination
Representation	Many variants	Parse Tree	Real-valued vectors	Finite-state machine
Recombination	Depend on representation	Exchange of subtrees	Discrete or intermediary	No
Mutation	Depend on representation	Random change in trees	Gaussian perturbation	Gaussian perturbation
Selection	Fitness proportional	Fitness proportional	Uniform random	Deterministic
Replacement	Many variants	Many variants	(λ,μ) or (λ + μ)	(λ + μ)
Specialty	Emphasis on crossover	Need huge population	Self-adaptation of mutation step size	Self-adaptation of mutation step size

(Talbi, 2009)

Genetic Algorithm (Pseudocode)

```
Input: Population_size, Problem_size, P_crossover, P_mutation
Output: S_best
Population ← InitializePopulation(Population_size,
Problem_size);
EvaluatePopulation(Population);
S_best ← GetBestSolution(Population);
while ¬StopCondition() do
    Parents ← SelectParents(Population, Population_size);
    Children ← ∅;
    foreach Parent_1, Parent_2 ∈ Parents do
        Child_1, Child_2 ← Crossover(Parent_1, Parent_2,
        P_crossover);
        Children ← Mutate(Child_1, P_mutation);
        Children ← Mutate(Child_2, P_mutation);
    end
    EvaluatePopulation(Children);
    S_best ← GetBestSolution(Children);
    Population ← Replace(Population, Children);
end
return S_best;
```

- How to formulate the problem
  - How to represent genomes? → encoding
  - How to define fitness/objective function?
- How to define the crossover operator?
- How to define the mutation operator?
- How to generate next generation?
- How to define stopping criteria?

Application of Evolutionary Computation

- EC in finance problem
- EC for data preparation
- EC for scheduling and allocation
- EC in data mining and recommendation system

Application of Evolutionary Computation in Finance: portfolio selection

- parameter optimization task
- the fitness function is calculated from the achieved return, the risk and additional constraints.
- Arnone dkk (1995): using GA
- Chang dkk (1998): GA + Tabu Search

Application of Evolutionary Computation in Finance: time series prediction

UNIVERSITAS GADJAH MADA

- Minimize the quadratic deviation of the prediction model to the real time series: target function
- to optimize the selection of input data and the strategy parameters
  - Minerva and Poli (2001): GA to optimize the strategy parameters for an ARMA-model
  - Mufti and Musdholifah (2020): GA to optimize the strategy parameters for an linier regression model of consumer price index prediction
- To predict through symbolic regression.
  - Koza (1990): father of GP: symbolic regression with GP
  - Yoshihara dkk (2000): GP and MA

Application of Evolutionary Computation: data preparation

- The implementation of genetic algorithm in SMOTE (Synthetic Minority Oversampling Technique) for handling imbalanced dataset problem
  (Tallo and Musdholifah, 4th International Conference on Science and Technology (ICST), 1-4, 2018)

Application of Evolutionary Computation: scheduling, timetabling and allocation

UNIVERSITAS GADJAH MADA

- Multi-objective Genetic Algorithm Model for Thesis Examination Scheduling (musdholifah 2016)
- Combination of Genetic Algorithm and Tabu List for Exam Scheduling (Sumihar and Musdholifah, 2019)
- Office Space Allocation Using Genetic Algorithm
  (Musdholifah and Utomo, 2019)
- Genetic Algorithm for Thesis Supervisor Allocation Problem
  (Miftahuljannah and Musdholifah, 2020)

Application of Evolutionary Computation: recommendation system and data mining

UNIVERSITAS GADJAH MADA

- Rule-Based and Genetic Algorithm for Automatic Gamelan Music Composition

  (Hastuti, Azhari, Musdholifah and Supangah, International Review on Modelling and Simulations (IREMOS) 10 (3), 202-212, 2017)

- Book Recommender System Using Genetic Algorithm and Association Rule Mining

  (Mustika and Musdholifah, Computer Engineering and Applications Journal 8 (2), 85-92, 2019)

UNIVERSITAS GADJAH MADA

Terima Kasih

Mengakar Kuat Menjulang Tinggi