# Metaheuristics: Cheat Sheets Cheat Sheet by jlobera.up via cheatography.com/169448/cs/35487/

#### **Evolutionary Computation**

#### **Evolutionary Computing**

Evolutionary Computing is a research area within **computer science**. As the name suggests, it is inspired by *Darwin's theory of natural evolution*.

In an environment with limited resources, the **fittest individuals survive**. Also, they have more chances to have **offspring**.

Evolutive Algorithms Terminology	
Individual	Represents a solution
Phenotype	The representation of an individual
Genotype	The representation used for solving the problem
Gene	A simple value from the genotype
Fitness	A numeric value that represents the quality of the solution
Population	It is a group of individuals that recombine and mutate their properties. The initial population is randomly created
Selection of parents:	The parents must be selected based on their fitness
Crossover (Repro- duction)	The parents inherit their characteristics to their offspring.
Mutation	Individuals modify their characteristics or behavior to improve themselves
Survival	The fittness. individuals

survive and can live more

time

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### Evolutive Algorithms Terminology (cont)

Termin-	If you know the value of good
ation	fitness, the algorithm can stop
Condition	when you find an individual
	with good fitness

### Pseudocode

#### BEGIN

INI TIALISE population with random candidate solutions; EVA LUATE each candidate; REPEAT UNTIL ( TERMIN ATION CONDITION is satisfied ) DO 1 SELECT parents; 2 RECOMBINE pairs of parents; 3 MUTATE the resulting offspring; 4 EVALUATE new candid ates; 5 SELECT indivi duals for the next genera tion; OD END

### **Evolutionary Programming (EP)**

#### **Evolutionary Programming (EP)**

In the classical example of EP, predictors were evolved in the form of finite state machines.

A *finite state machine* (FSM) is a transducer that can be stimulated by a finite alphabet of input symbols and can respond in a finite alphabet of output symbols.

It consists of a number of states S and a number of state transitions.

The state transitions define the working of the FSM: depending on the current state and the current input symbol, they define an output symbol and the next state to go to.

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#### Mutation operators to generate new FSMs

The idea was evolving finite state machines (FSMs). There are five generally usable mutation operators to generate new FSMs: Changing an output symbol Changing a state transition Adding a state Deleting a state Changing the initial state

Evolutionary Programming Terminology	
Repres- entation	Real-valued vectors
Parent selection	Deterministic (each parent creates one offspring via mutation)
Recomb- ination	None
Mutation	Gaussian perturbation
Survivor selection	$(\mu + \mu)$
Specialty	Self-adaptation of mutation step sizes

#### Particle Swarm Optimization

#### Particle Swarm Optimization

Inspired by the movement of a flock of birds when searching for food.

#### **Particle Representation**

Each particle *i* represents a solution for the problem. In the time t, it has a position  $xi(t) \in \mathbb{R}d$  and a velocity  $vi \in \mathbb{R}d$ .

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Reproduction (crossover or recombination)

several sections.

parent randomly.

point.

1 point

N point

Uniform

crossover

crossover

**Mutation** 

Bitwise mutation

Random

resetting

Uniform

mutation

Swap

mutation

**Differential Evolution** 

seen as vectors.

distance

**Diferencial Evolution (DE)** 

It is a robust algorithm for solving

*continuous multidimensional optimization problems.* In this algorithm, individuals as

The novelty is the mutation operator, that

uses three individuals for mutate another

one, and the mutation depends on the

crossover

This technique divides the

parents into two sections

randomly choosing a crossover

The parents are divided into

For each gene, it copies the

gene of the first or the second

Consists of randomly selecting

Consists of randomly selecting

one or several genes and resets

one or several genes and changing their values.

It randomly selects one or

random value between the

several genes and chooses a

minimum and maximum values.

Consists of randomly selecting

two elements and swapping

its values.

their values.

#### Position and Velocity Update

The positions and velocities are updated following the next equations, where *Pbest i* is the best position where the particle *i* has been, *Gbest* is the best location founded until the moment, r1 and  $\Box$   $\Box$ 2 are random numbers between 0 and 1, and *w*, *c*1, and *c*2 are hyper parameters. Those last values can be initialized at 0.9 and gradually reducing it until

## Genetic Algorithms (GA)

0.1.

## Genetic Algorithms (GA)

John Holland proposed genetic Algorithms in the 1970s. Initially, they were called *"Reproductive Plans."* These algorithms are maybe the most famous of the evolutive algorithms family.

The inspiration comes from the **DNA structure**, which is people's genetic code. All the information is stored in chromosomes that have a lot of genes. Holland's proposal consists of representing the solutions by binary arrays.

#### Selection of Parents

Roulette selection	You can imagine a roulette where each section is assigned to an individual. If we have 10 individuals, the roulette is divided into 10 sections. The section size is proportioned to the indivi- dual's fitness.
Tournament selection	It consists of randomly choosing k individuals and selecting the fittest one. k represents the tournament size.

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#### **Differential Evolution Example**

Video: http://youtu.be/BsfJDg0a0Z4

Differential Evolution Terminology	
Repres- entation	The individuals are repres- ented as vectors whose entries are the variables values.
Mutation	Mutation is the main operation in Differential Evolution. The new individual <i>v i</i> is calculated as follows: $vi = xr1 + F(xr2 - \Box$ $\Box r3$ )
Crossover	For each variable k of $u \square$ $\square$ , the value is selected randomly between $vi$ or $\square$ $\square i$
Selection	The selection is performed by tournament.

## **Constraint Handling**

#### **Disadvantages of Constrains**

In general, the presence of constraints will divide the space of potential solutions into two or more disjoint regions, *the feasible region*, containing those candidate solutions that satisfy the given feasibility condition, and the *infeasible region* containing those that do not.

#### **Penalty Functions**

Static Relies on the ability to specify a distance metric that accurately reflects the difficulty of repairing the solution, which is obviously problem-dependent, and may also vary from constraint to constraint

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### Penalty Functions (cont)

The fitness function used to
evaluate the population is a
combination of the distance
function for constraint i with a
death penalty for all solutions
violating constraints

Is a distance metric of the infeasible point to the feasible region

## Constrains in EA

The presence of constraints implies that not all possible combinations of variable values represent valid solutions to the problem at hand.

Unfortunately, constraint handling is not straightforward in an EA, because the variation operators are typically "blind" to constraints.

There is no guarantee that even if the parents satisfy some constraints, the offspring will satisfy them as well.

#### **Repair Functions**

Takes an infeasible point and generates a feasible solution based on it. In some problems, this technique is relatively simple.

In general, defining a repair function may be as complex as solving the problem itself.

#### **Evolution Strategies (ES)**

#### **Evolution Strategies (ES)**

The goal is to solve *continuous multidimensional optimization problems*.

The main characteristic is the **self-adaptation of parameters**. It means that some evolutive algorithm parameters change during the execution.

Those parameters are included in the individual representation and **evolve** at the same time that the solution.



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# **Evolution Strategies Terminology**

	3
Indivi- dual's Repres- entation	The individuals' solutions are represented as vectors whose inputs are the values of the variables
Mutation	The individual's position is modified by adding a random number, noise, to each entry
Recomb- ination	In ES there are two recomb- ination variants
Interm- ediate recomb- ination	The values of the parents are averaged.
Discrete recomb- ination	One of the parent's values is randomly chosen with equal chance for either parents
Parent selection	Parent selection in ES is completely random, because here the whole population is seen as parent
Survivor Selection	$(\mu, \lambda)$ selection, where only the best $\mu$ offspring are selected. $(\mu + \lambda)$ selection, where the best $\mu$ individuals (from the union of parents and offspring) are selected
Specialty	Self-adaptation of mutation step sizes

#### **Genetic Programming**

#### Genetic Programming (GP)

Automatically solves problems without requiring the user to know or specify the structure of the solution in advance. The main idea of GP is to evolve a population of computer programs, where individuals are commonly represented as syntax trees.

## Elements of a GP individual

Terminals	Leave nodes in a syntax tree.
	Variables that can be
	predefined or randomly
	generated.
Functions	Internal nodes in a syntax tree. Operations

#### **Genetic Programing Terminology**

Initial population	<ol> <li>Full, where all the trees are randomly created, and all the leaves have the same depth</li> <li>Grow, each node selects an element randomly from either the function set or the terminal set</li> <li>Ramped half-and-half where half of the population is created with the full technique</li> </ol>
	and the other half with grow
Selection	Tournament Selection
Crossover	Classic Crossover
Mutation	Subtree mutation, randomly selects a mutation point in a tree and substitutes the subtree rooted there with a randomly generated subtree

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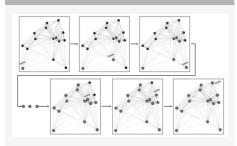
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# Ant Colony Optimization (ACO)

# Ant Colony Optimization (ACO)

Solves problems of finding paths in graphs. It is inspired by the ants' behavior when searching for food. The ants leave pheromones that allow other ants to follow the path to food. The more ants go for a specific path, the more pheromones.

#### Example



In this algorithm, an artificial ant must simulate a path starting at a specific point. It moves node by node, choosing based on the pheromones of each path.

#### Ant Colony Terminology

- Cij Path from the node i to the node j
- Tij Pheromones in the path from the node i to the node j
- Nij Heuristic in the path from the node i to the node j
- p Evaporation rate, between 0 and 1

#### Steps

First	All the pheromones can be initia- lized with a small value.
Second	Ants start to move around the graph node by node using the previous equation.
Last	The pheromones must be updated. Ants deposit pheromones to their path propor- tional to its distance. The pheromones evaporate.

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