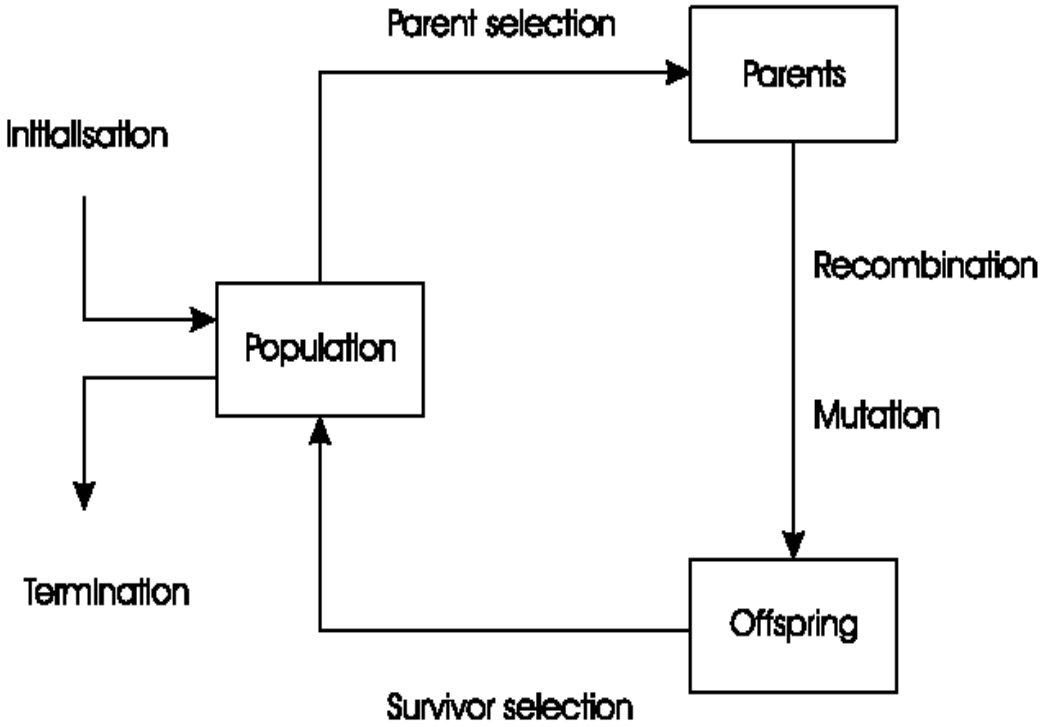
COMP 4752
Computational Intelligence

Lecture 18
Evolutionary Algorithms

Recap: EC Metaphor

1. Population of individuals exists in an environment with limited resources
2. Competition for those resources causes selection of fitter individuals that are better adapted
3. Those individuals reproduce to form new generation of individuals through recombination and mutation
4. New individuals have fitness evaluated, high fitness individuals chosen to reproduce, pass on good traits
5. Over time, natural selection causes fitness to rise

Evolutionary Algorithms



Evolutionary Algorithms

1. INITIALIZE population w/ random individuals
2. REPEAT UNTIL (termination condition)
3. EVALUTE population / individual fitness
4. SELECT parents with high fitness
5. COMBINE parents to form offspring
6. MUTATE resulting offspring
7. NEXT POP = select from [pop,offspring,parents]

Main Components of an EA

- Representation (definition of individuals)
- Evaluation / Fitness Function
- Population (Size, Shape)
- Parent Selection Mechanism
- Variation Operators (Recombination / Mutation)
- Survivor Selection Mechanism (Replacement)

Representations

- Candidate solutions (individuals) exist in phenotype space
  - Phenotype = Actual Solution Candidate
- They are encoded in chromosomes, exist in genotype space
  - Genotype = Representation of Phenotype
  - Encoding: Phenotype -> Genotype
  - Decoding: Genotype -> Phenotype (1 to 1)
- In order to find global optimum, every possible solution must be represented in genotype space

Representation Example

Phenotype

5	3			7				
6			1	9	5			
	9	8					6	
8				6				3
4			8		3			1
7				2				6
	6					2	8	
			4	1	9			5
				8			7	9

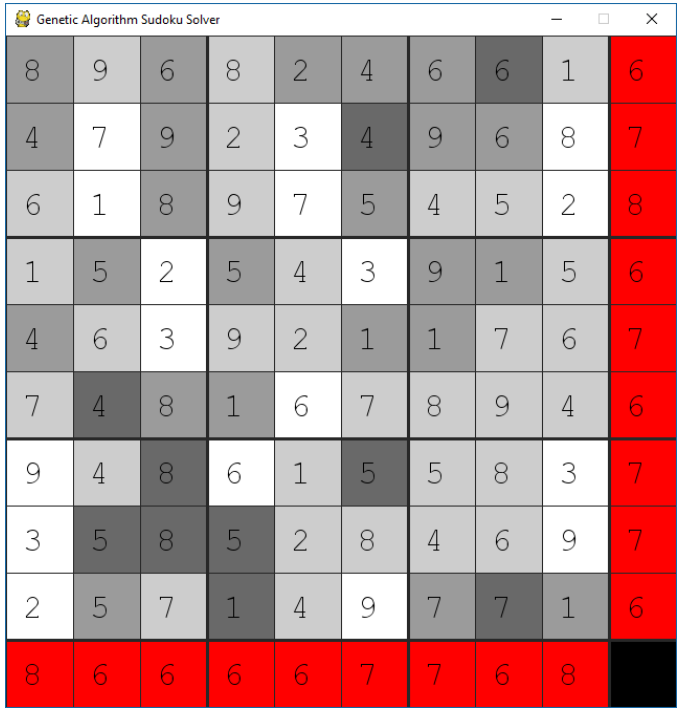
Genotype

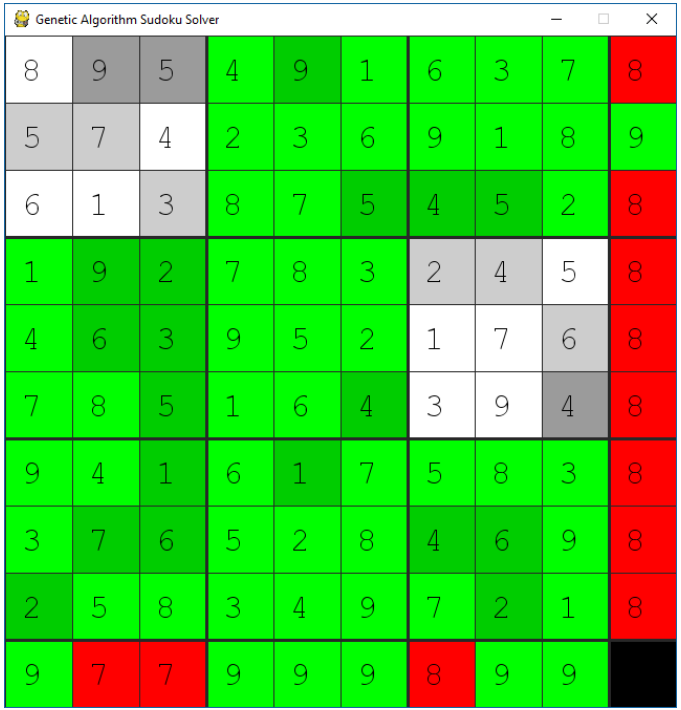
[5,3,0,0,7,0,0,0,0,…0,7,9]

Evaluation (Fitness) Function

- Represents the requirements that the population should adapt to
- Assigns a real-values fitness to each phenotype with forms the basis for selection
  - More fine-grained different values, the better
- Typically we talk about fitness being maximized
  - Some problems may be minimization

Example Fitness Function

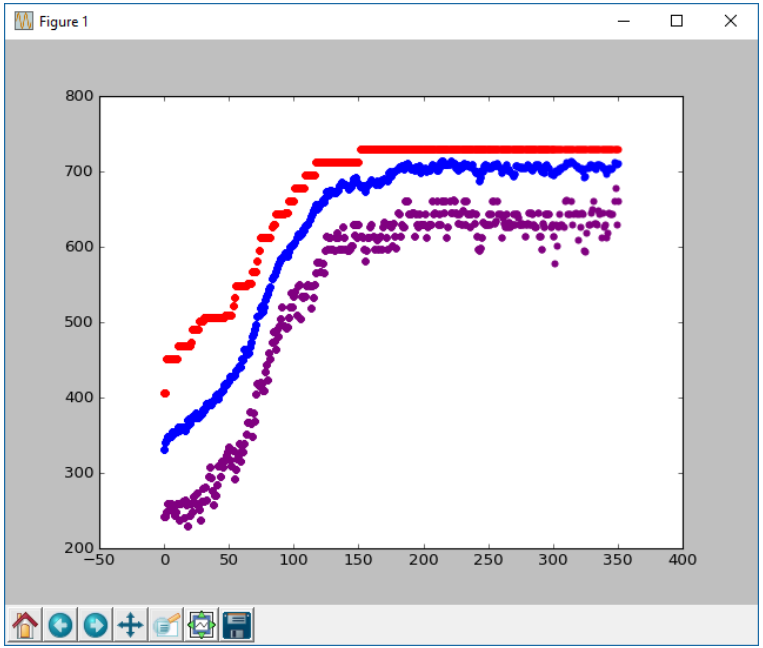


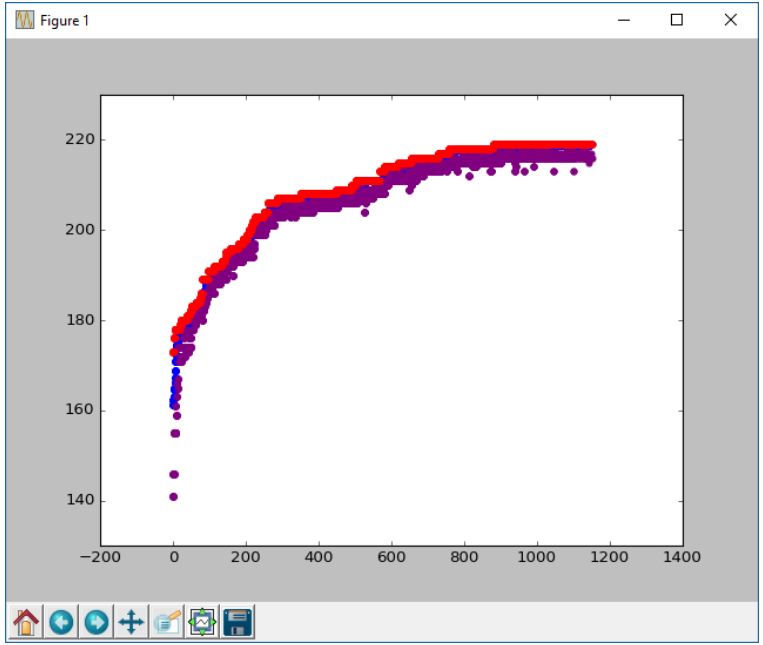


Population

- Holds (representation of) possible solutions
- Usually has a fixed size
- Some sophisticated EAs assert a special structure on the population (grid, etc)
- Selection operators usually take whole population into account (current generation)
- Diversity of population refers to the number of different fitnesses / phenotypes / genotypes

Population Diversity

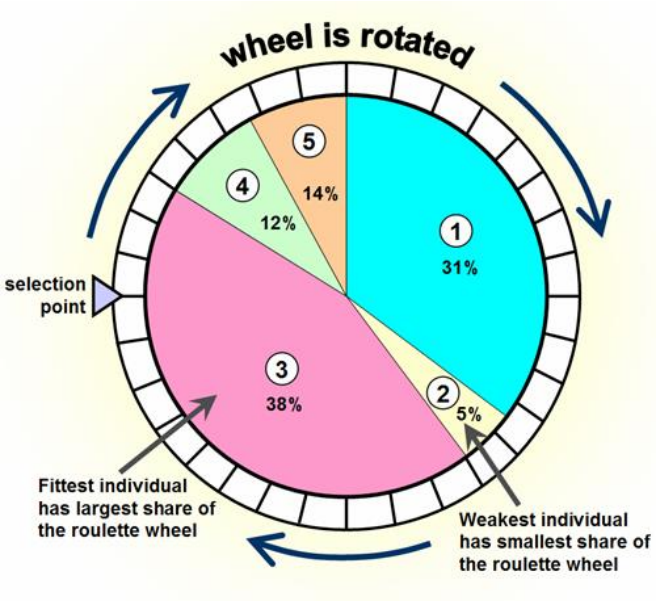




Parent Selection Mechanism

- Assigns variable probabilities of individuals as parents depending on their fitnesses
- Usually Probabilistic
  - High quality solutions more likely to reproduce (be a parent) but not guaranteed
  - Worst candidate usually has non-zero chance
- Stochastic nature can help escape local optima

Example Parent Selection



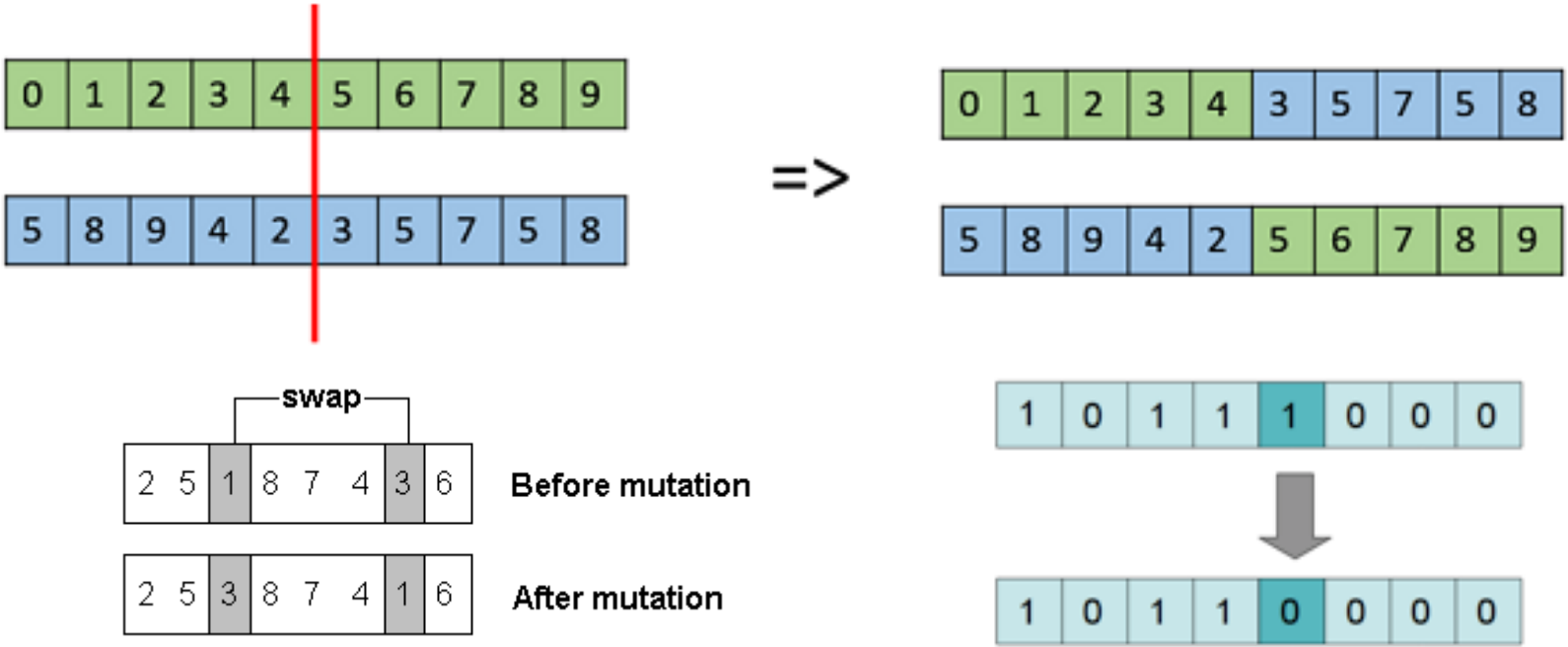
Roulette Wheel Selection

```
1. roulette_select(population)
2.     pop_fitness = [fit(p1), fit(p2), …, fit(pn)]
3.     max = sum(pop_fitness)
4.     pick = random(0, max)
5.     current = 0
6.     for i in len(population):
7.         current += pop_fitness[i]
8.         if (current > pick): return population[i]
```

Variation Operators

- Role is to generate new candidate solutions
  - From parents to children (offspring)
- Usually divided into two types according to their number of inputs:
  - Mutation Operator (1 input)
  - Recombination Operator (> 1 input)
  - 2 Inputs = Crossover
- Most EA use both recombination and mutation

Crossover / Mutation



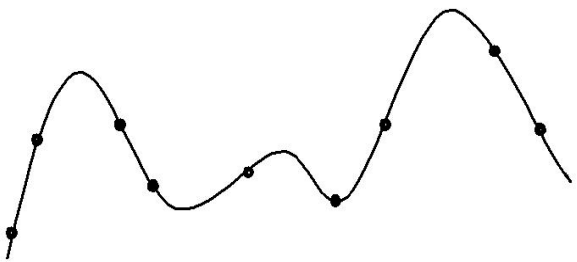
Survivor Selection

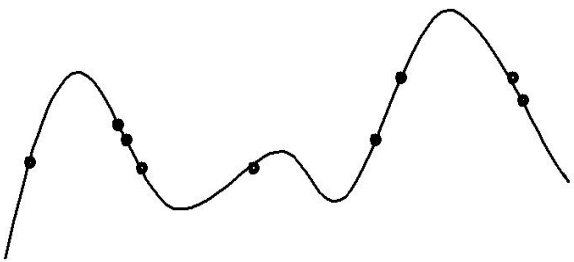
- Also called environmental selection
- Most EA use a fixed population size, and need a way of going from (parents + offspring) to next generation
- Often Deterministic
  - Fitness Based (rank all and select)
  - Age Based (prefer offspring)
  - Elitism (best n always live)

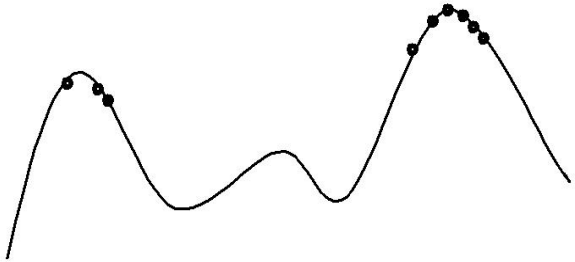
Initialization and Termination

- Initialization usually done randomly
  - Need to ensure even mixture of candidates
  - Can include existing solutions, heuristics
- Termination Condition
  - Reach some known / desired fitness
  - Reach a generation limit
  - Reach a minimum diversity
  - Reach a generation limit of no improvement

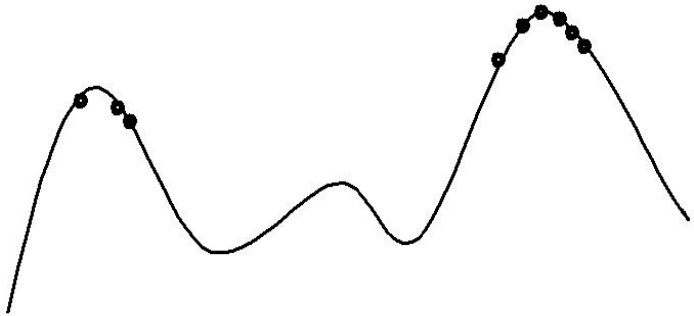
Typical Behaviour of an EA

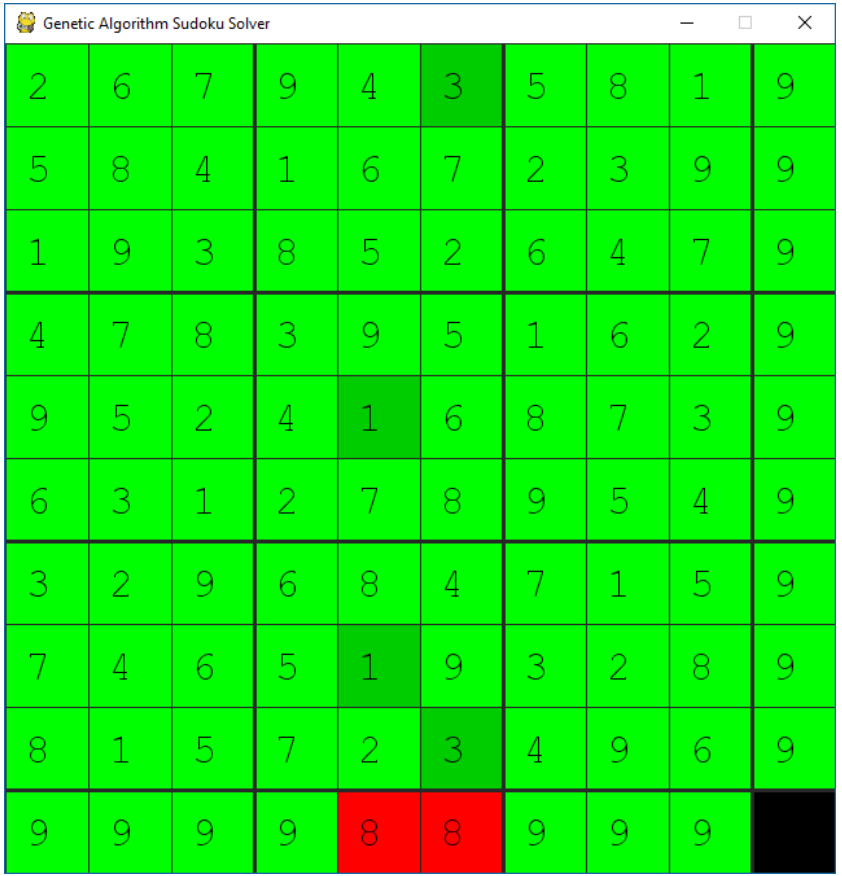




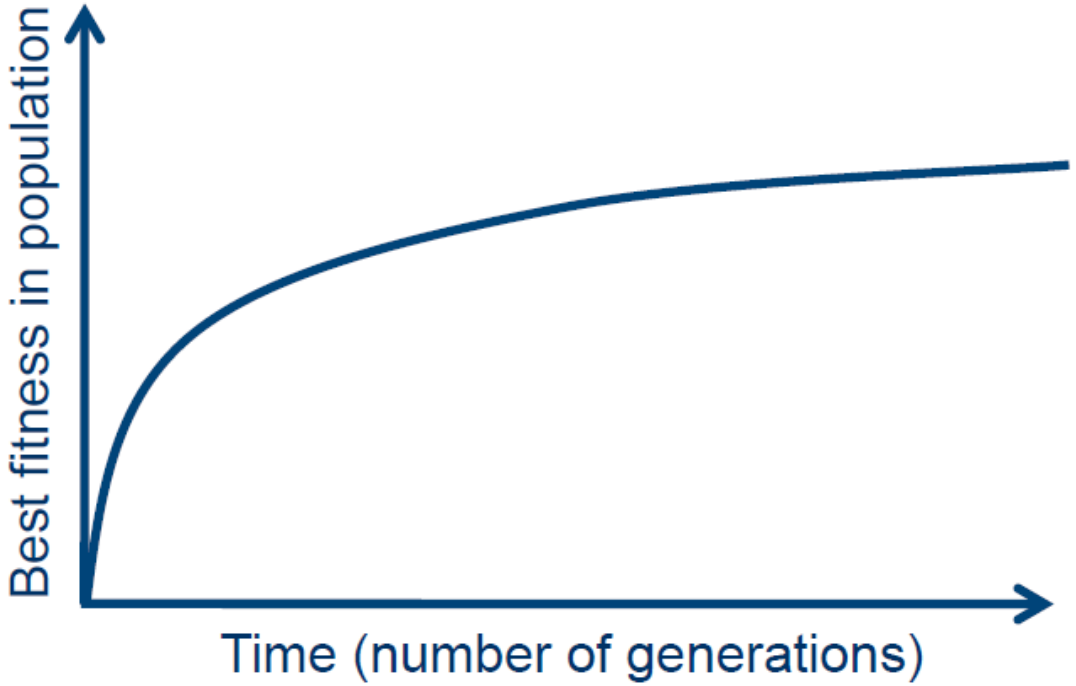


Local Maxima

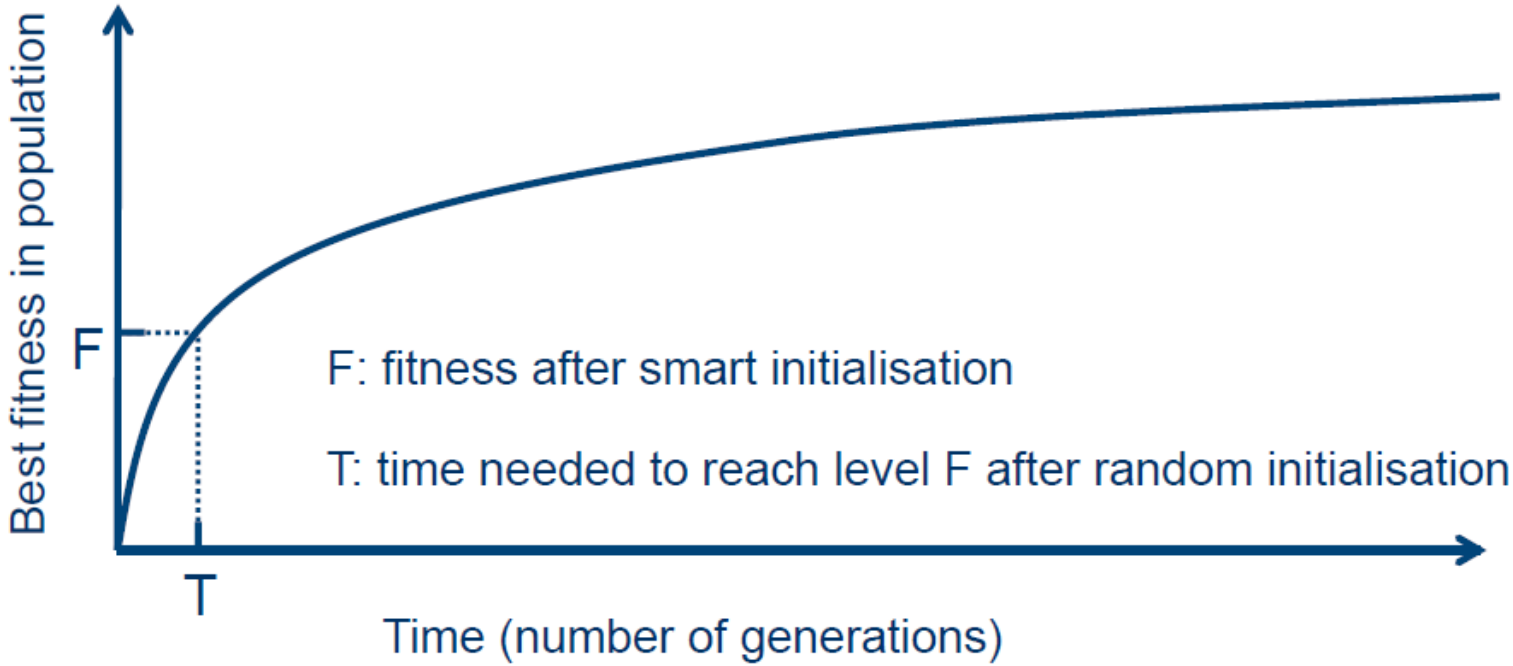




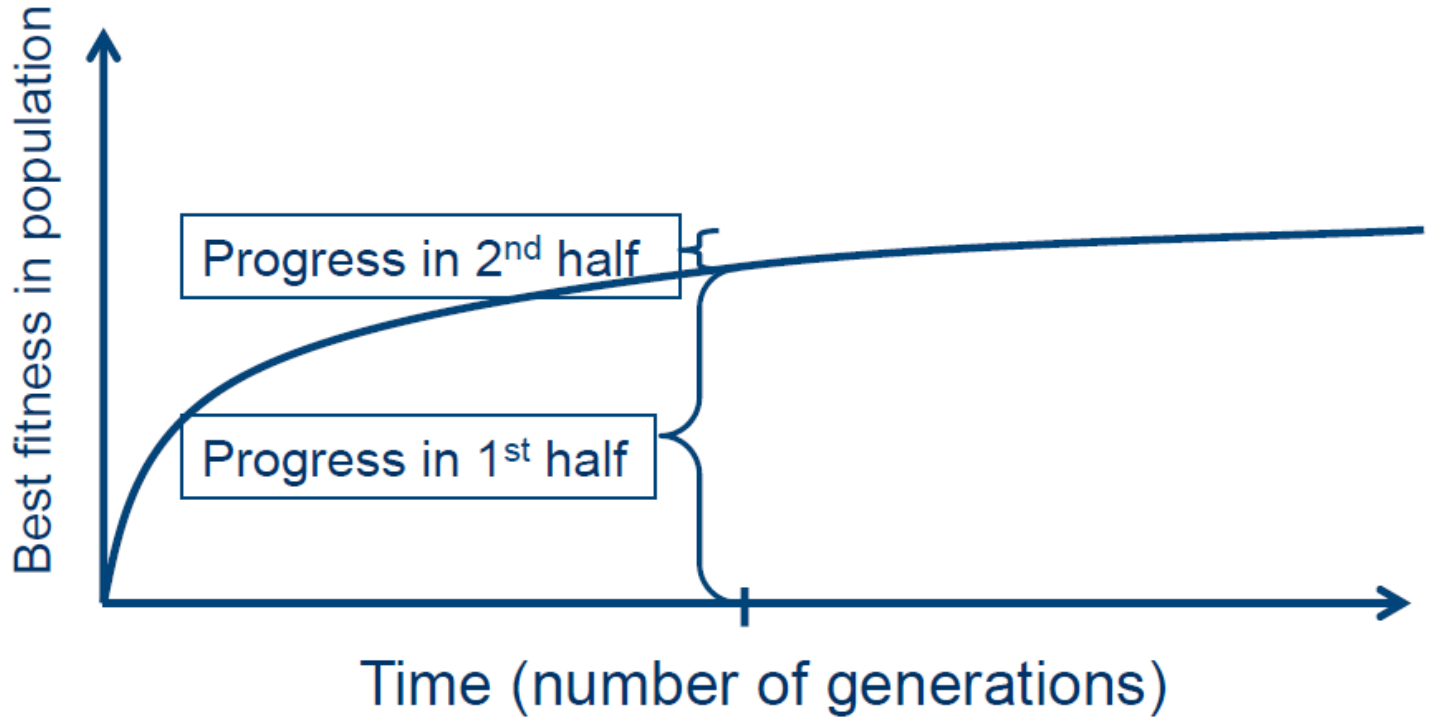
Typical GA Run



Smart vs. Random Initialization



Running Time vs. Fitness



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