Computational Intelligence

Unit # 2

Biology

- A gene is a sequence of DNA bases that code for a trait, e.g., eye color or ability to metabolize alcohol.
- An allele is a value of a trait. The eye color gene could have a blue allele or a hazel allele in different people.
- **Definition:** Evolution is the variation of allele frequencies in populations over time.

Mutation

- Mutations of data structures can be “good” or “bad.”
- A good mutation is one that increases the fitness of a data structure.
- A bad mutation is one that reduces the fitness of a data structure.

Theory of Evolution

- The theory of evolution is the body of thought that examines evidence and uses it to deduce the consequences of the fact that evolution is going on all the time.
- You do not need to accept the theory of evolution in biology to do evolutionary computation.
- Evolutionary computation uses the ideas in the theory of evolution, asserting nothing about their validity in biology.

Variation and Selection in Biology

- There are two opposing forces that drive evolution: variation and selection.
- Variation is the process that produces new alleles and, more slowly, genes. Variation can also change which genes are or are not expressed in a given individual.
- Selection is the process whereby some alleles survive and others do not.
- Variation builds up genetic diversity; selection reduces it.

Variation and Selection in EC

- Evolutionary computation operates on populations of data structures.
- It accomplishes variation by making random changes in these data structures and by blending parts of different structures. These two processes are called mutation and crossover, and together are referred to as variation operators.
- Selection is accomplished with any algorithm that favors data structures with a higher fitness score. There are many different possible selection methods.

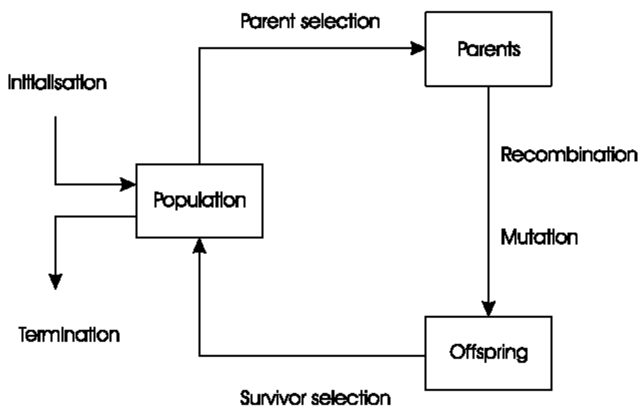
Survival of the Fittest

- "evolution is the result of survival of the fittest" is a pretty good description of many evolutionary computation systems.
- When we use evolutionary computation to solve a problem, we operate on a collection (population) of data structures (creatures).
- These creatures will have explicitly computed fitnesses used to decide which creatures will be partially or completely copied by the computer (have offspring)

Basic Idea of EAs

- Generate a population of structures
- Repeat
  - Test the structures for quality
  - Select structures to reproduce
  - Produce new variations of selected structures
  - Replace old structures with new ones
- Until Satisfied

General Scheme of EAs

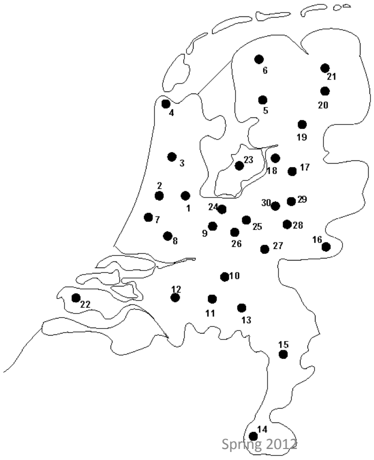


A Typical Evolutionary Algorithm Cycle

- Step 1: Initialize the population randomly or with potentially good ***solutions***.
- Step 2: Compute the ***fitness*** of each individual in the population.
- Step 3: Select parents using a ***selection procedure***.
- Step 4: Create offspring by ***crossover*** and ***mutation*** operators.
- Step 5: Compute the ***fitness*** of the new offspring.
- Step 6: Select members of population to die using a ***selection procedure***.
- Step 7: Go to Step 2 until termination criteria are met.

Traveling Sales Person Problem

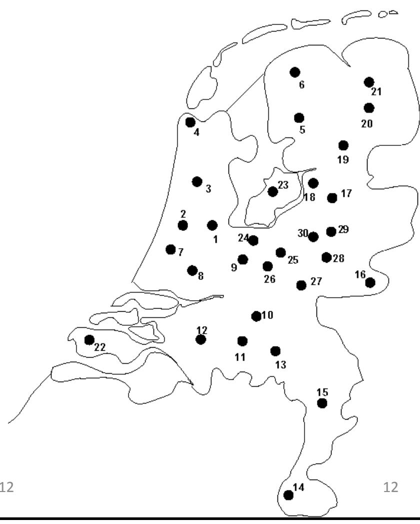
- Given a number of cities and the costs of traveling from one city to any other city, what is the cheapest round-trip route that visits each city exactly once and then returns to the starting city?



Permutation Representation: TSP

- Problem:
  - Given n cities
  - Find a complete tour with minimal length
- Encoding:
  - Label the cities 1, 2, … , *n*
  - One complete tour is one permutation (e.g. for n =4 [1,2,3,4], [3,4,2,1] are OK)
- Search space is BIG:

  for 30 cities there are 30! ≈ 10^{32} possible tours



TSP: Nearest Neighbor

	A	B	C	D	E	F	G	H
A	0	8	3	1	4	9	3	6
B	8	0	5	10	11	4	3	6
C	3	5	0	8	7	1	5	12
D	1	10	8	0	9	11	6	4
E	4	11	7	9	0	5	17	3
F	9	4	1	11	5	0	4	1
G	3	3	5	6	17	4	0	7
H	6	6	12	4	3	1	7	0

- Start with A: A – D – H – F – C – B – G – E Cost?
- Start with E: E – H – F – C – A – D – B – G Cost?
- Start with G: G – B – F – H – E – A – D – C Cost?

Initialize The Population

- Suppose the population size is 6

Candidate Solutions
A C B F H D E G
H B G E A C D F
A H G C B D F E
E G B C D H F A
F H A D C B E G
C D B A H E G F

Compute Fitness

Candidate Solutions	Fitness
A C B F H D E G	43
H B G E A C D F	52
A H G C B D F E	49
E G B C D H F A	47
F H A D C B E G	49
C D B A H E G F	56

	A	B	C	D	E	F	G	H
A	0	8	3	1	4	9	3	6
B	8	0	5	10	11	4	3	6
C	3	5	0	8	7	1	5	12
D	1	10	8	0	9	11	6	4
E	4	11	7	9	0	5	17	3
F	9	4	1	11	5	0	4	1
G	3	3	5	6	17	4	0	7
H	6	6	12	4	3	1	7	0