CSE/ECE 848 Introduction to Evolutionary Computation

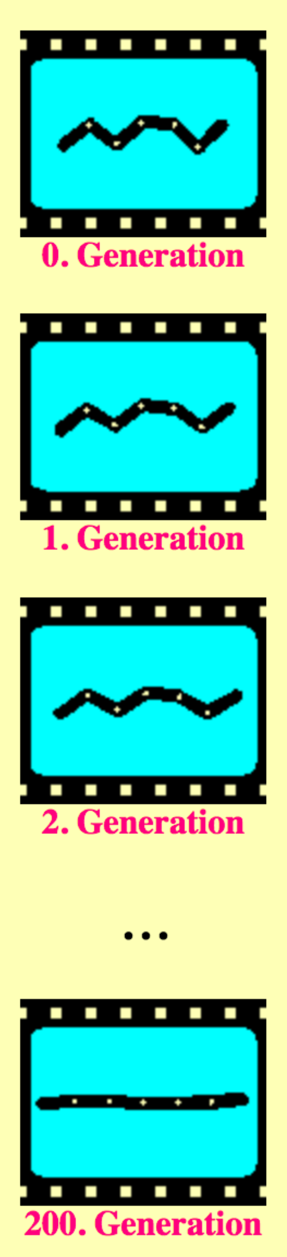
Module 3 - Lecture 10 - Part 1

Evolutionary Strategies - Introduction

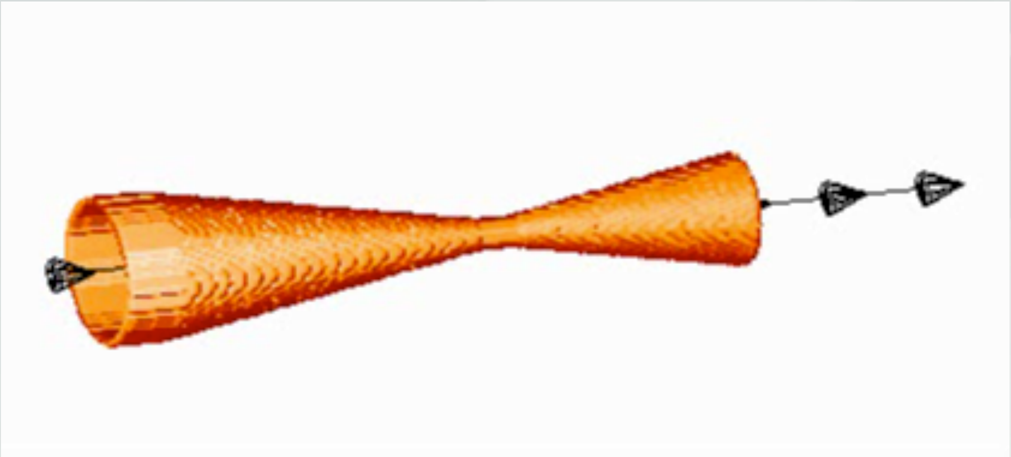
Wolfgang Banzhaf, CSE
John R. Koza Chair in Genetic Programming

Early ES

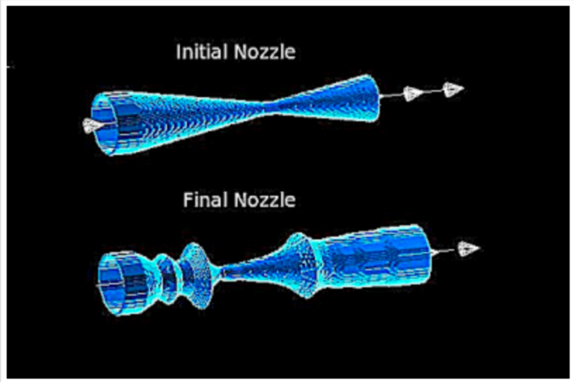
- Early ES was developed in 1964 by Ingo Rechenberg and his fellow student Hans-Paul Schwefel in Germany
- Primarily driven by the need to optimize parameters of experimental, often engineering, models with real-valued parameters
- First application was the configuration of a 5-hinged planar surface in a wind tunnel to get the lowest drag (which would be all 5 surfaces co-planar in the direction of the wind)



Famous Experiment driven by ES



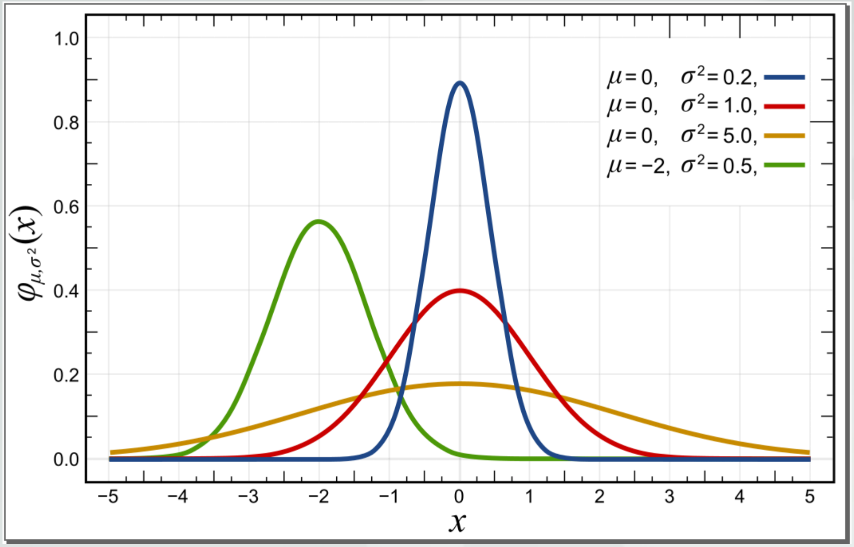
Optimizing a jet nozzle for thrust



Evolutionary Strategies

- Problem solution is a n-dimensional real-valued vector x associated with some function F(x), the fitness function
- Initial population consists of a set of N parent vectors x_i, where each x_i has values, either created randomly from the range of available values, or from an existing (suboptimal solution)
- Each offspring vector x_i' is created from a parent x_i by adding a Gaussian random variable with zero mean and arranged standard deviation to each parameter of x_i

Evolutionary Strategies II



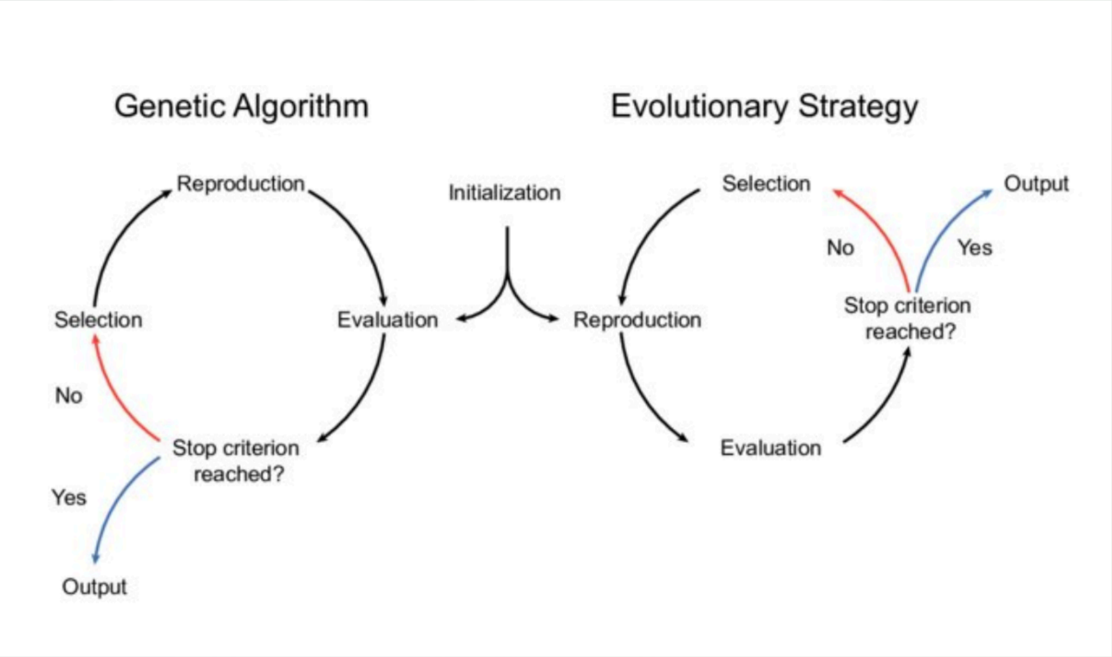
Probability Density Distribution Function for the Gaussian ("Normal") Distribution

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$

- Selection determines whether x_i' or x_i "survives" to the next generation based on F(x) (fitness or error)
- Recombination between two parent genomes is possible, with appropriate selection

Evolutionary Strategies III

- Process continues until a sufficiently correct solution is discovered or until other termination criterion is reached



Christian Brand, Shaping and Modelling Electronically Excited States of Indoles, PhD Thesis, 2013

Differences to GAs

- ES does not involve itself at all with genotype/phenotype differences. It works directly on the phenotype.
- The order of reproduction and selection is different from GAs.
- Mutation is the most important variation operator
- Recombination is a secondary variation operator

Basic Comparison

Evolutionary Strategies	Genetic Algorithms
Float/Mixed Integer Representation	Discrete Representations
Mutation Emphasis	Crossover Emphasis
Self adaptation	Constant Parameters (typically)
Small population sizes	Larger Population sizes
Deterministic Selection	Probabilistic Selection
Focus on Theory of Convergences	Focus on Theory of Schemas

Evolutionary Strategy Outline

- A typical ES experiment is represented using quantities that characterize the population and offspring numbers with a pair of Greek letters and an operation:

- (μ op λ)-ES

- Where μ represents the parent population count and λ represents the offspring number count. “op” explains possible replacement methods

Replacement Methods

- The two major models of replacement are:

- op = + pool of offspring and parents compete to be in next generation (an “elitist” strategy)
- op = , pool of offspring compete among themselves for next generation, parents automatically expire after a generation

Basic Algorithm

1. Initialize population $P_n=\{a_1, a_2, \ldots, a_n\}$
2. Select parents to create λ offspring
3. Apply mutation (and possibly recombination) until offspring pool is filled
4. If “,” op, select μ best offspring for next pop
5. If “+”, select μ best offspring +parents for next pop
6. Goto 2 until “good enough”

Evolution Strategy Types

There are a number of subtypes of ES, which include:

- The simple (1+1)-ES: A hill climber
- The (μ+1)-ES: The first multi-membered ES
- The (μ+λ)-ES, and
- The (μ,λ)-ES