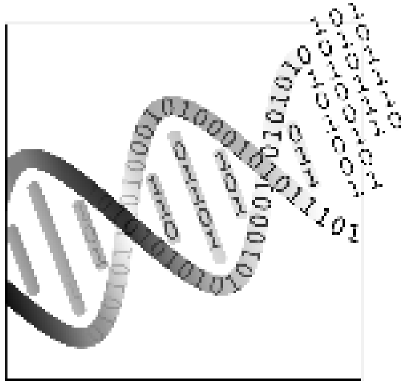
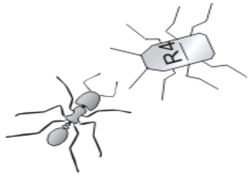
Viability Evolution
Multi-objective Optimization with Diversity Maintenance





Companion slides for the book *Bio-Inspired Artificial Intelligence: Theories, Methods, and Technologies* by Dario Floreano and Claudio Mattiussi, MIT Press

What you will learn in this lecture

- Viability instead of selection of the best
- Viability Evolution algorithm
- Comparisons with Genetic Algorithm and with NSGA-II
- Memetic evolutionary algorithms

Revisiting selection

I should premise that I use the term Struggle for Existence in a large and metaphorical sense . . . . Two canine animals in a time of dearth, may be truly said to struggle with each other... But a plant on the edge of a desert is said to struggle for life against the drought, though more properly it should be said to depend on the moisture **(Darwin, On the Origin of Species, 1860)**

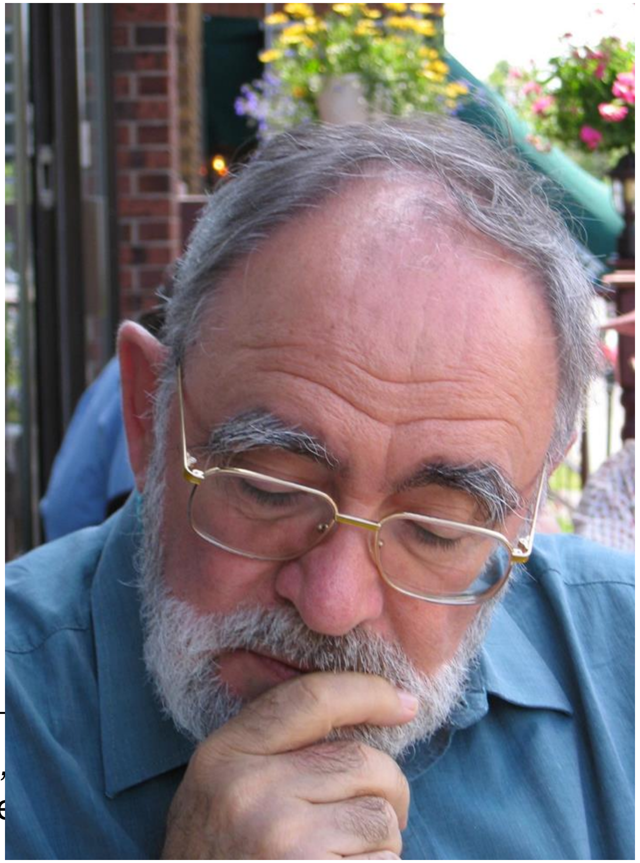
Viability

To stay alive, an organism must keep physiological parameters within upper and lower viability boundaries

Cannon, 1939
The wisdom of the body

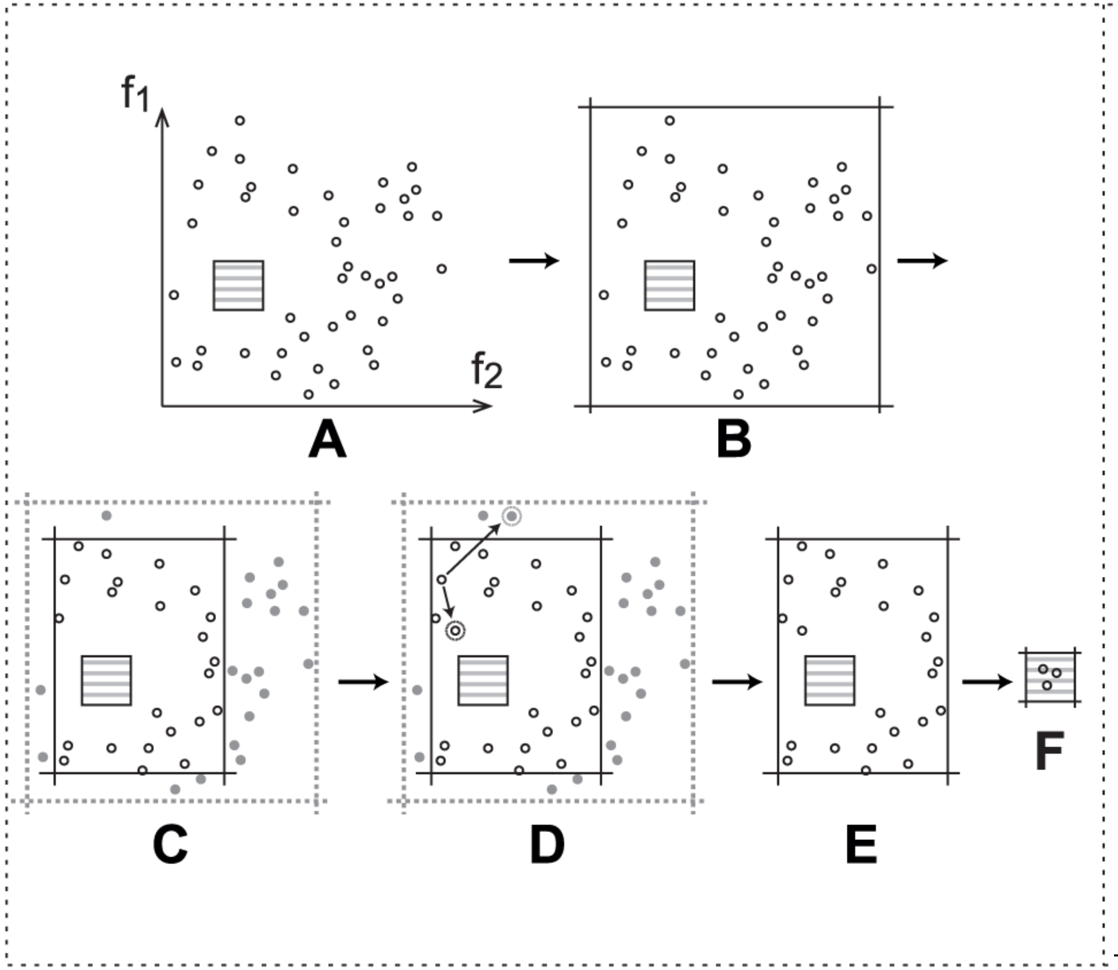
Ashby, 1960
Design for a Brain

Aubin, 1991
Viability Theory



Viability Evolution (ViE) *Maesani, Mattiussi, Floreano 2014*

Reproduce all viable solutions, where viability is defined by minimum fitness and constraint feasibility. Population size can vary, and there can be population extinctions



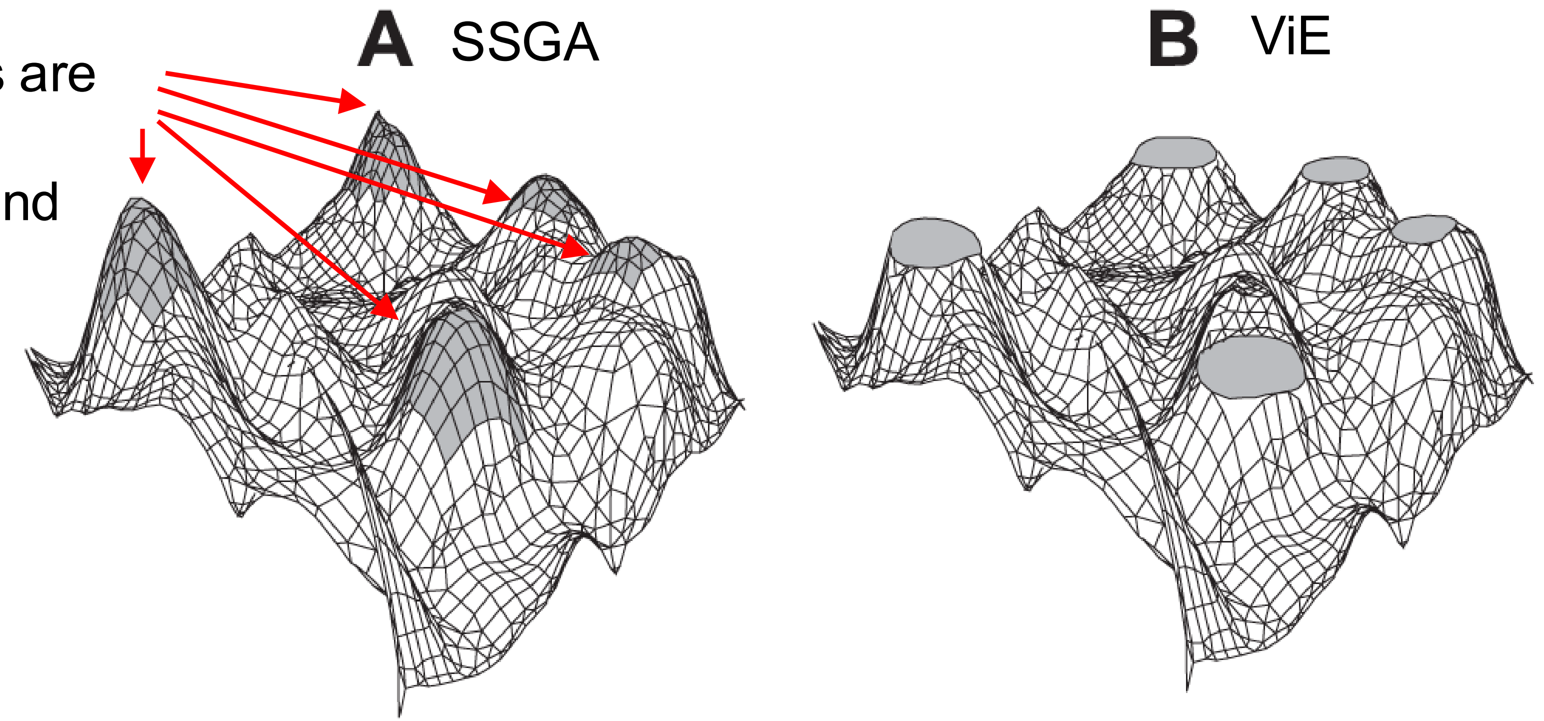
Max_size= maximum population size
t=0
(**A**) Set *Target_boundaries* for each objective and create initial population (*Max_size)*
(**B**) Enlarge *boundaries(t)* to encompass all solutions

while t≤*T* or *boundaries(t)=Target_boundaries*
(**C**) Shrink *boundaries(t)* towards *Target_boundaries*
(**D**) Reproduce viable individuals with mutations (up to *Max_size)*
(**D**) Eliminate non-viable individuals

Standard Simple GA and ViE on Multimodal functions

To make the two algorithms comparable, we must put an arbitrarily chosen limit to the objective function in SSGA all individuals and add fitness sharing to SSGA to promote diversity

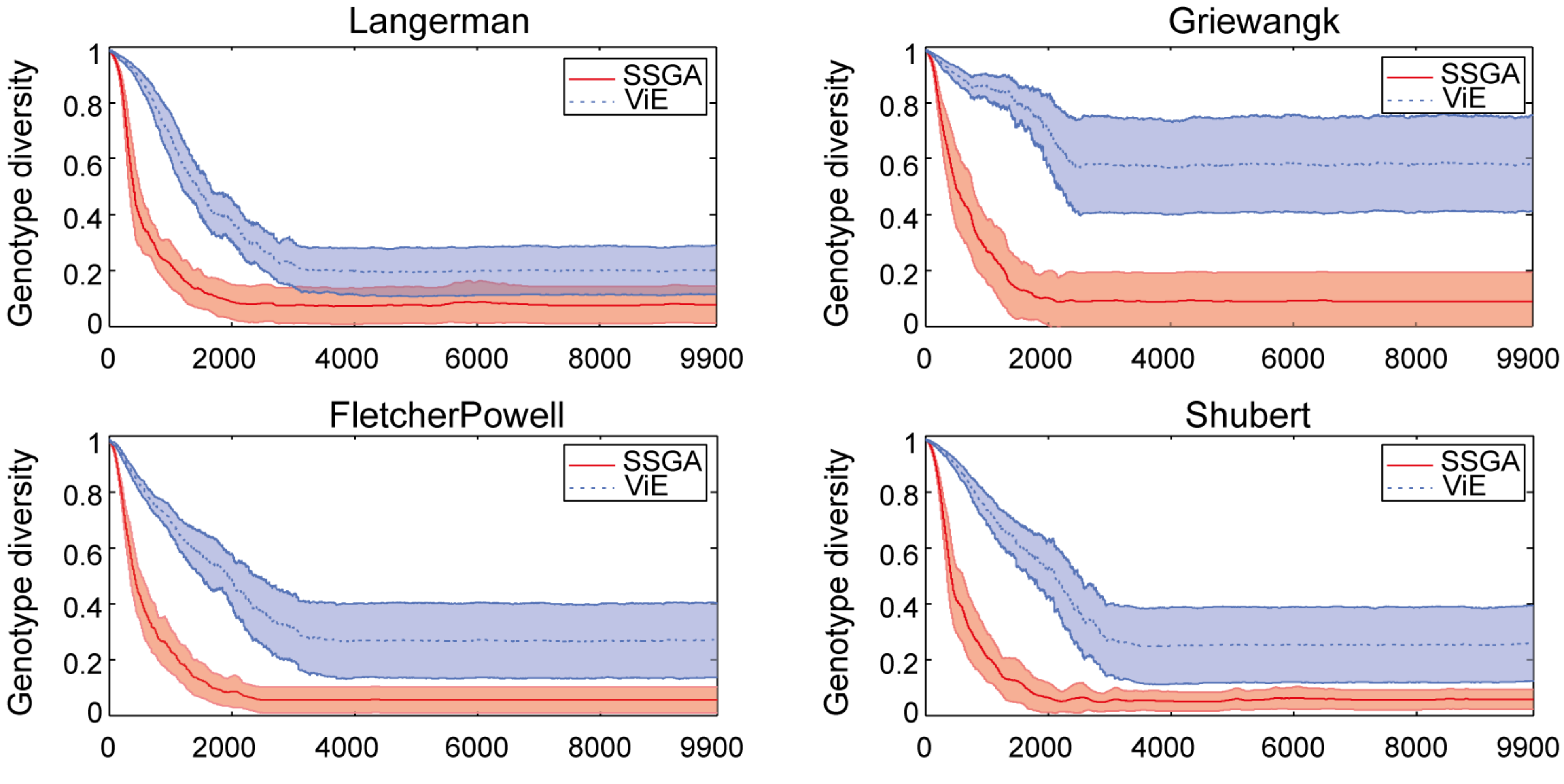
Final solutions are expected to distribute around peak regions



Target regions match peak regions of single-objective optimization

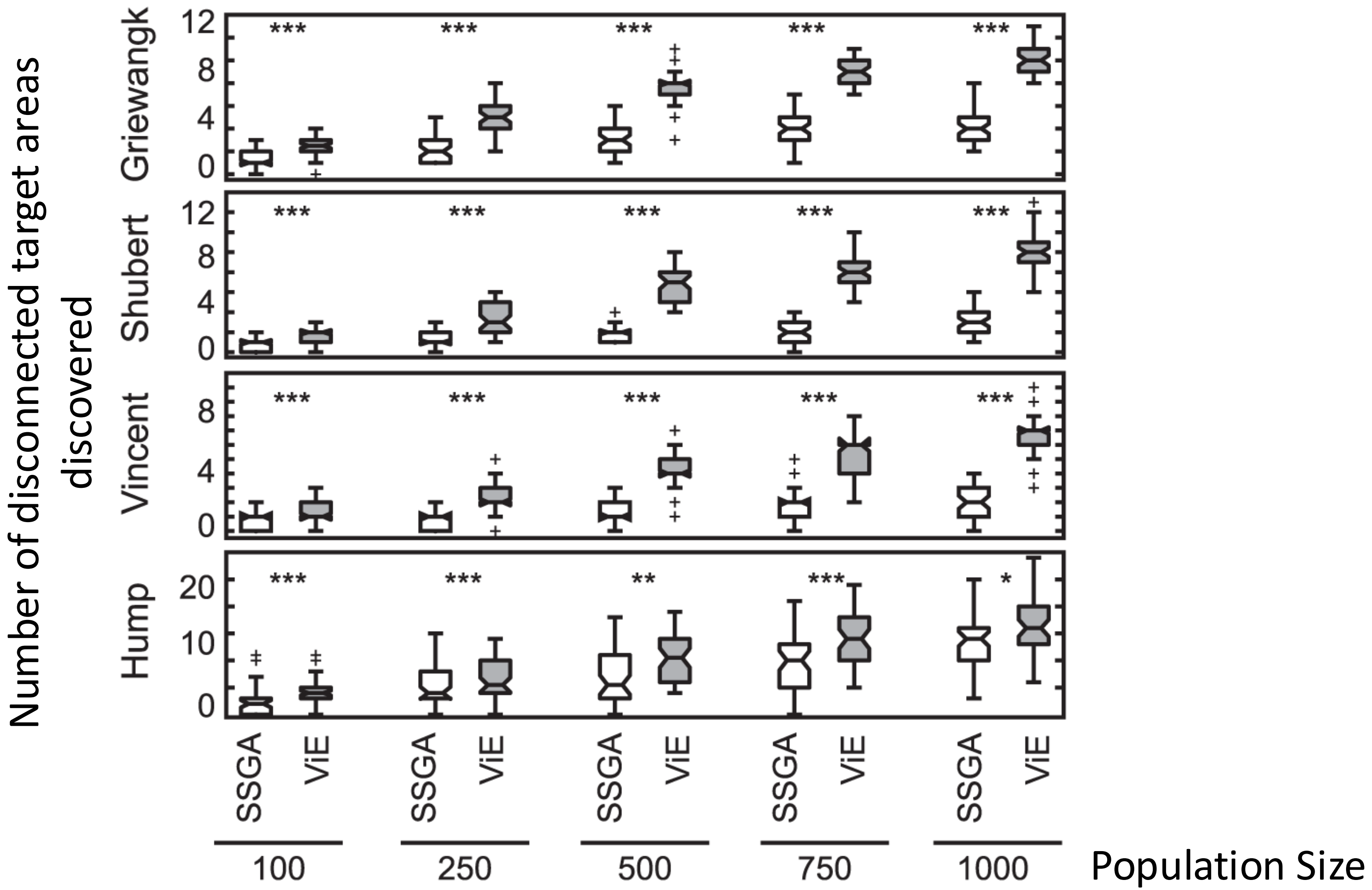
ViE population can grow up to size of SSGA population

Viability can maintain higher genetic diversity



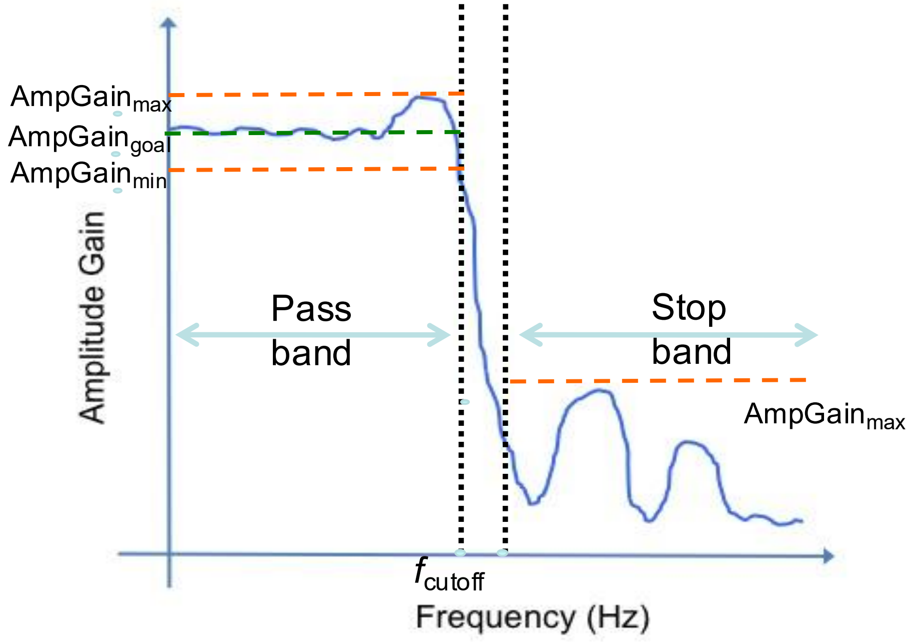
Selected plots from 10 benchmark multimodal functions

Vie can find solutions in more disconnected target areas

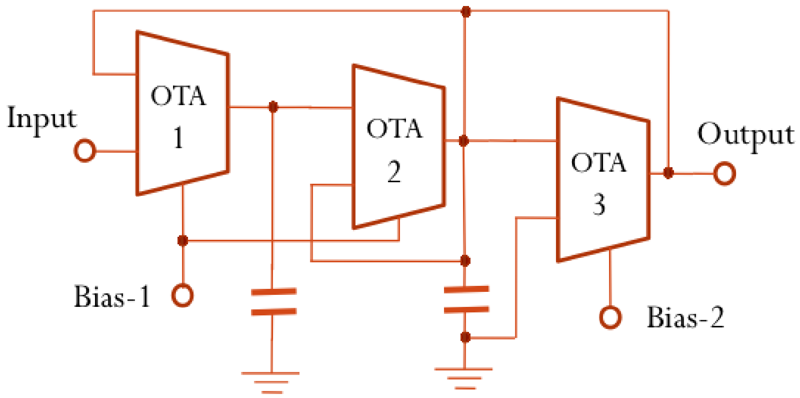


Multi-objective Optimization of Electronic Low Pass Filter

Low pass filters are analog circuits used in all amplifiers and are critical for amplification quality



OTA – Operational Transconductance Amplifier



Tunable 2nd Order Low Pass Filter

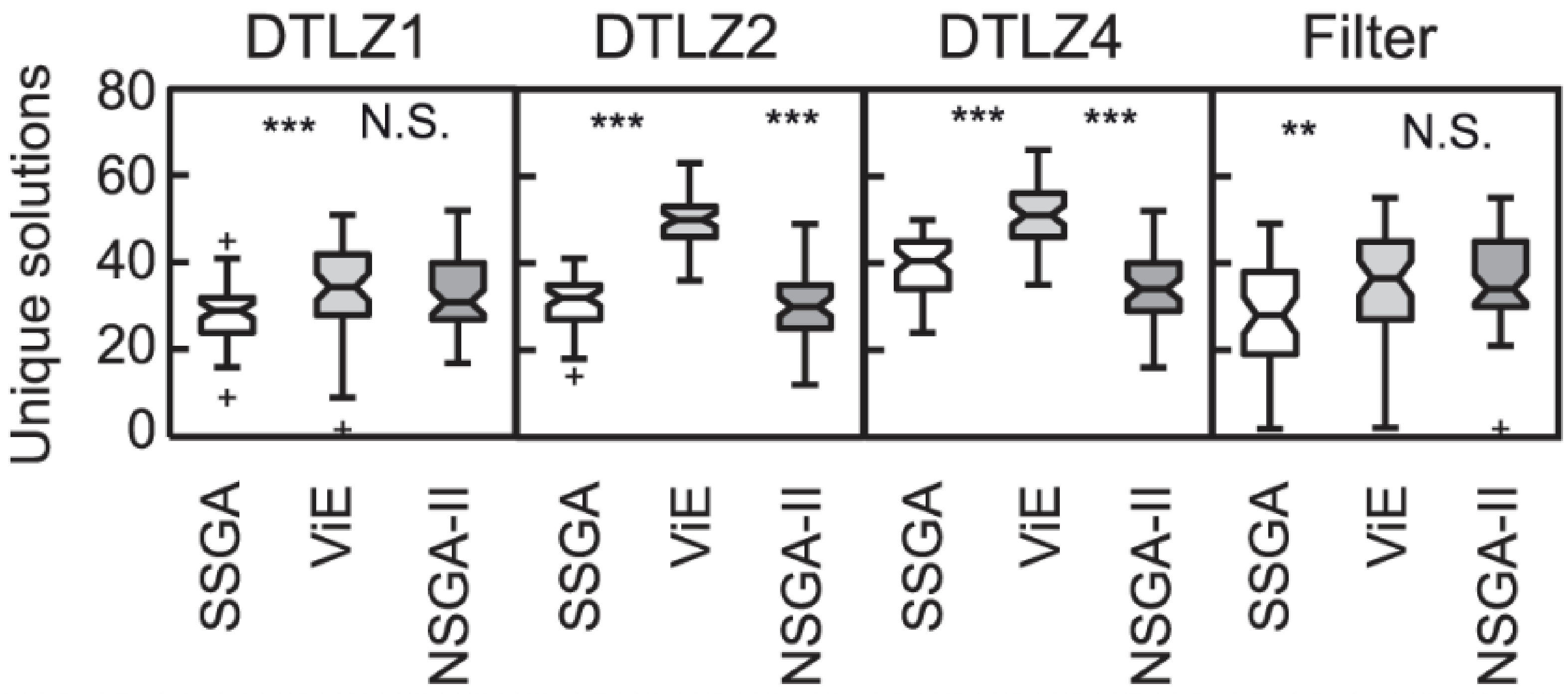
(Redrawn from "Active Filter Design using Operational Transconductance Amplifiers: A Tutorial", R.L. Geiger and E.Sanchez-Sinencio, IEEE Circuits & Devices Magazine, Vol. 1, pp.20-32, 1985)

1. Gain-Bandwidth (GBW) product
2. Pass Band Flatness
3. Stop Band Attenuation

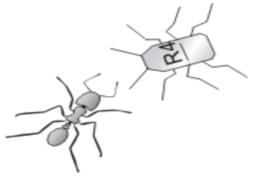
The values of the filter's characteristics can be modified by changin voltages at the two bias points

Multi-objective Optimization: SSGA, NSGA-II and ViE

ViE discovers more unique solutions than SSGA with fitness sharing and objective weighting, and equal or larger number of unique solutions than NSGA-II

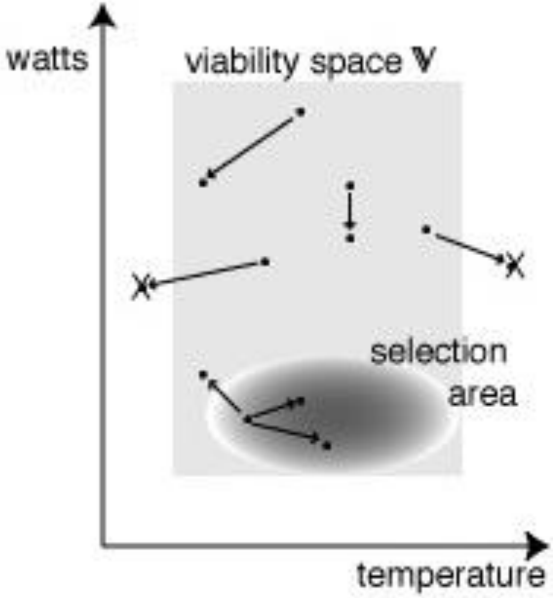


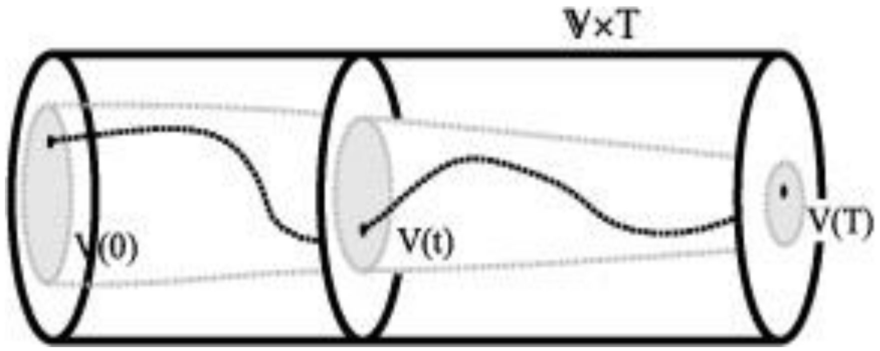
DTLZ is a standard set of multiobjective problems for benchmarking algorithms



Memetic Viability Evolution

Memetic Evolution: A combination of an evolutionary algorithm with another search method within the population. Typicalls, the search method is a learning algorithm (e.g., RL)
- In Viability Evolution one can apply conventional proportionate selection (or tournament selection) to regions of the viability space and thus combine the strengths of two evolutionary algorithms





Evolution over time

Memetic Viability Evolution has beaten all best single-objective and multi-objective optimization algorithms in a class of standard benchmark problems in terms of performance and computation time (Maesani, Iacca, Floreano, 2016)

Checkpoints

- Describe how does viability differ from selection
- Describe the main steps of the Viability Evolution algorithm
- What is Memetic Evolution