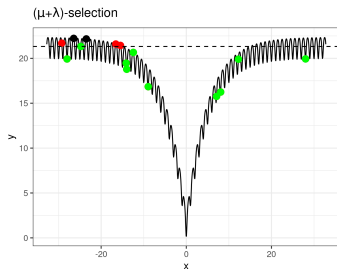
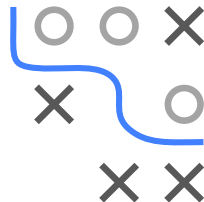


Optimization in Machine Learning

Evolutionary Algorithms ES / Numerical Encodings



Learning goals

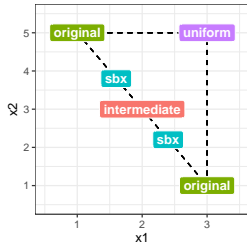
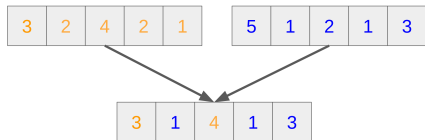
- Recombination
- Mutation
- A few simple examples

RECOMBINATION FOR NUMERIC

Options for recombination of two individuals $\mathbf{x}, \tilde{\mathbf{x}} \in \mathbb{R}^d$:

- **Uniform crossover:** Choose gene j of parent 1 with probability p and of parent 2 with probability $1 - p$
- **Intermediate recombination:** Offspring is created from mean of two parents: $\frac{1}{2}(\mathbf{x} + \tilde{\mathbf{x}})$
- **Simulated Binary Crossover (SBX):** generate **two** offspring

$$\bar{\mathbf{x}} \pm \frac{1}{2}\beta(\tilde{\mathbf{x}} - \mathbf{x}), \quad \bar{\mathbf{x}} = \frac{1}{2}(\mathbf{x} + \tilde{\mathbf{x}}), \quad \beta \in [0, 1] \text{ uniformly at random}$$

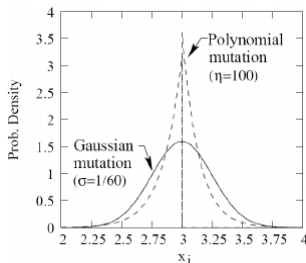


MUTATION FOR NUMERIC

Mutation: Individuals get modified

Example for $\mathbf{x} \in \mathbb{R}^d$:

- **Uniform mutation:** Select random gene x_j and replace it by uniformly distributed value (within feasible range).
- **Gauss mutation:** $\mathbf{x} \pm \mathcal{N}(0, \sigma \mathbf{I})$
- **Polynomial mutation:** Use a different distribution instead of normal distribution

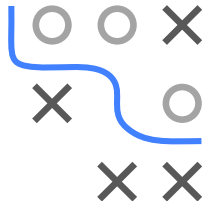
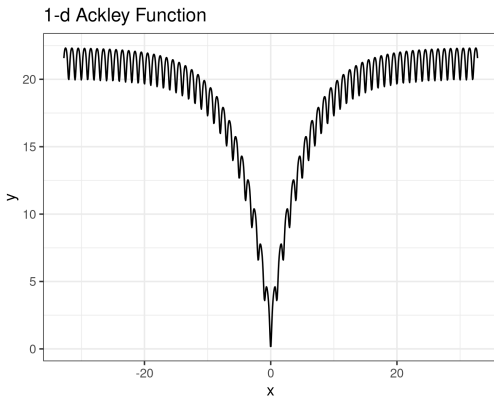


Source: K. Deb, D. Deb. Analysing mutation schemes for real-parameter genetic algorithms, 2014

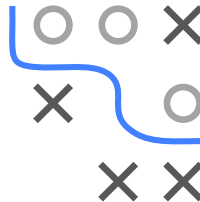


EXAMPLE OF AN EVOLUTIONARY ALGORITHM

(Simple) EA on 1-dim Ackley function on $[-30, 30]$. Usually, for optimizing a function $f : \mathbb{R}^d \rightarrow \mathbb{R}$, individuals are encoded as real vectors $\mathbf{x} \in \mathbb{R}^d$.

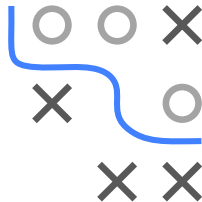
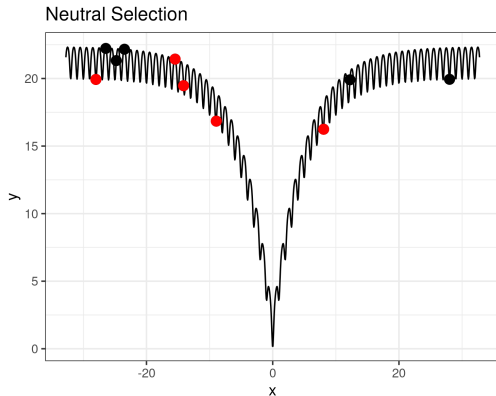


Random initial population with size $\mu = 10$



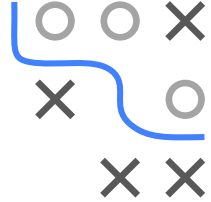
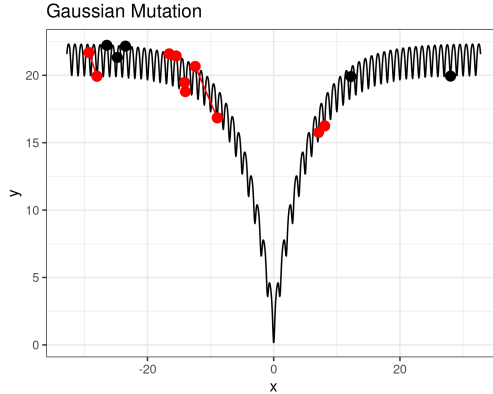
EXAMPLE 1: ACKLEY FUNCTION

We choose $\lambda = 5$ offsprings by neutral selection (red individuals).



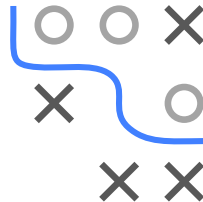
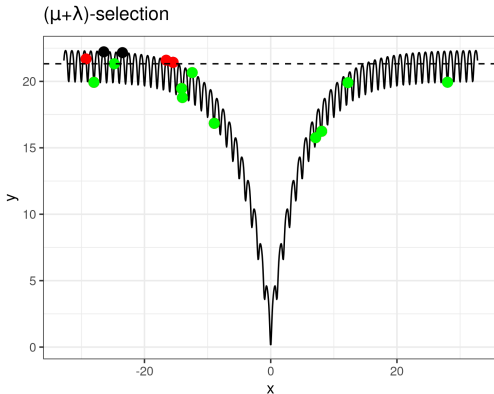
EXAMPLE 1: ACKLEY FUNCTION

Use Gaussian mutation with $\sigma = 2$, but without recombination.



EXAMPLE 1: ACKLEY FUNCTION

Use $(\mu + \lambda)$ selection. Selected individuals are marked in green.



EXAMPLE 1: ACKLEY FUNCTION

After 50 iterations:

