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EVOLUTIONARY COMPUTATION

Adaptive Differential Evolution

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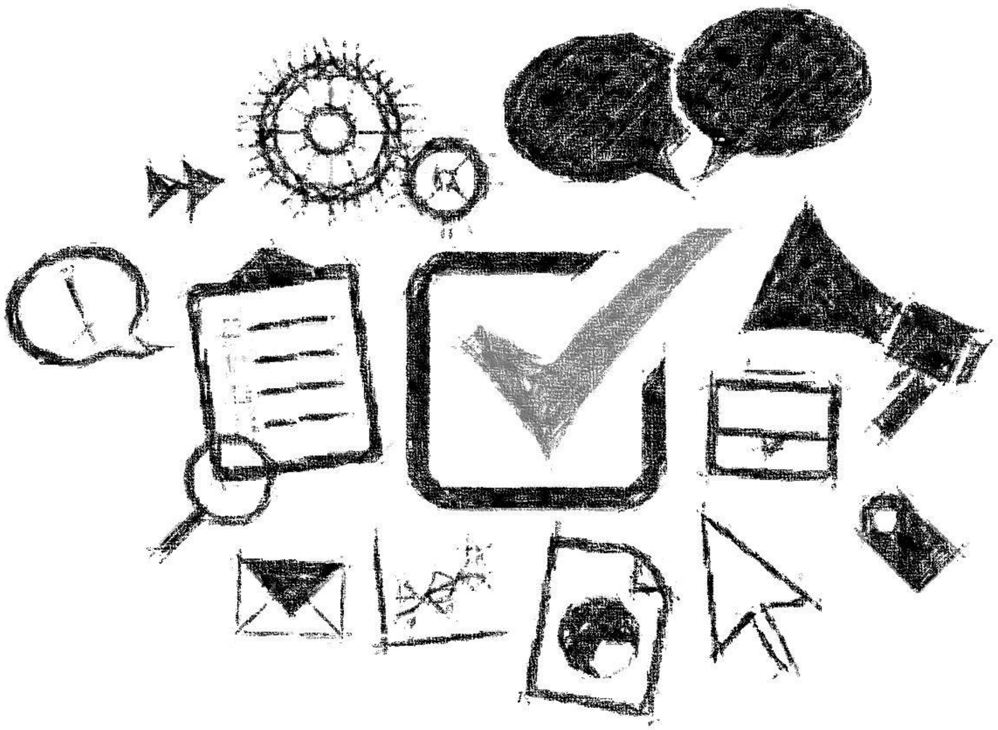


Differential Evolution

- **Metaheuristic optimizer / Evolutionary computation technique / Evolutionary algorithm**
- Rainer Storn & Kenneth V. Price – 1995
- Great for numerical single objective optimization

- Given $f : A \rightarrow \mathbb{R}$, $A \subseteq \mathbb{R}^{dim}$
- Find a set of parameters $\boldsymbol{x}_0$:
- $f(\boldsymbol{x}_0) \leq f(\boldsymbol{x}), \forall \boldsymbol{x} \in A$

1. Generate random set of solutions (first generation)
2. While stopping criteria not met do
   1. Use mutation and crossover operators to produce candidate solutions
   2. Select better one from the target and candidate solutions for the next generation
3. Return best-found solution

Control parameters

1. **Population size – *NP***
2. **Scaling factor – *F***
3. **Crossover rate – *CR***

- User-dependent algorithm setting

- Optimization performance – massively influenced
- “No free lunch” theorem

Population

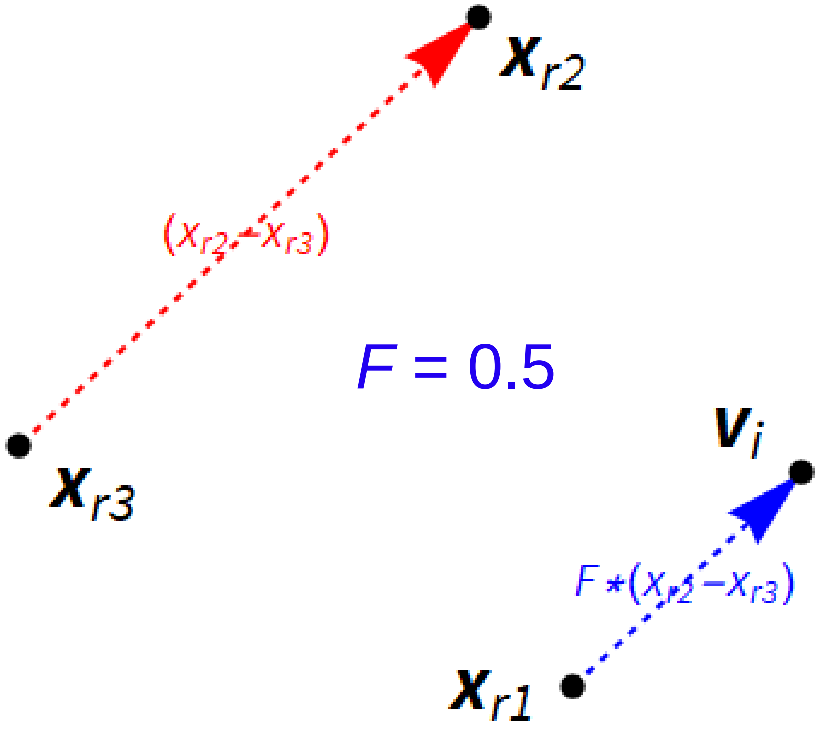
1. Population size – *NP*
   - Range – [4, inf]

- Smaller population => more generations
- Larger population => better search space coverage

Mutation operator

- Example: rand/1

- $\boldsymbol{v}_i = \boldsymbol{x}_{r1} + F \cdot (\boldsymbol{x}_{r2} - \boldsymbol{x}_{r3})$
  - $i \neq r1 \neq r2 \neq r3$



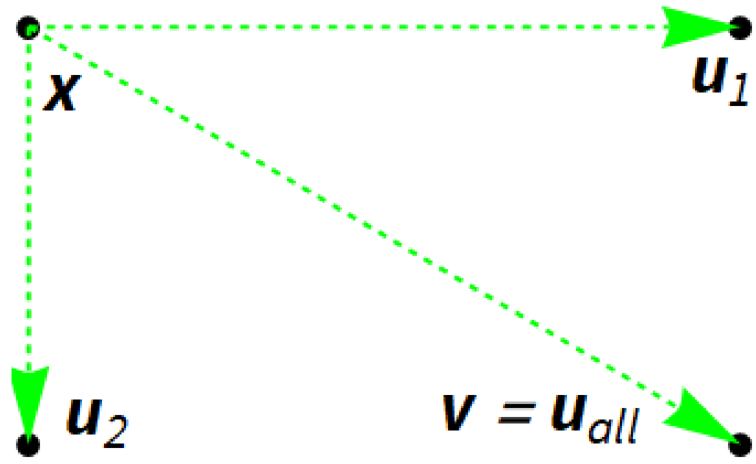
2. Scaling factor – *F*
   - Usual range [0, 2]

Crossover operator

- Example: binomial

- $u_{j,i} = \begin{cases} v_{j,i} & if\ U[0,1] \leq CR\ or\ j = j_{rand} \\ x_{j,i} & otherwise \end{cases}$

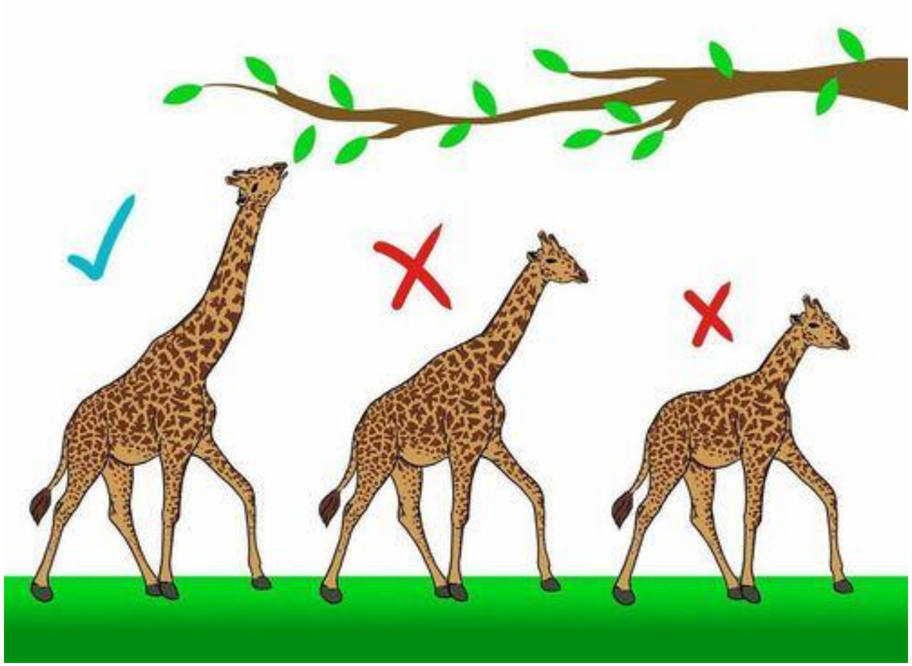
3. Crossover rate – *CR*
   - Range [0, 1]



Selection

- Target vs. candidate solution
- $\boldsymbol{x}_i$ vs. $\boldsymbol{u}_i$

- If $f(\boldsymbol{u}_i) \leq f(\boldsymbol{x}_i)$ then $\boldsymbol{u}_i$ goes to the next generation.



Control parameter adaptation

- "The answer to practitioners prayers."

- **Deterministic** / **Adaptive** / Self-adaptive

- Relatively easy for *F* and *CR*
- Not so easy for *NP*

- Usual practice
  - Find out what worked in the past (*F* and *CR*) and try similar values – **Adaptive**
  - Start with big population and gradually decrease its size – **Deterministic**

DISH timeline

What	How	When	IEEE CEC comp
DE	Original	1995	-
JADE	Current-to-*p*best/1	2009	-
SHADE	Historical memories	2013	3^{rd} (2013)
L-SHADE	Linear decrease of population size	2014	1^{st} (2014)
iL-SHADE	Optimization phase *F* and *CR* update	2016	4^{th} (2016)
Distance based parameter adaptation	Redefined success	2017	-
jSO	Current-to-*p*best-w/1	2017	2^{nd} (2017)
DISH	Distance adaptation for jSO	2019	2^{nd} (2019)
DISH-XX	Double crossover	2020	? (2020)

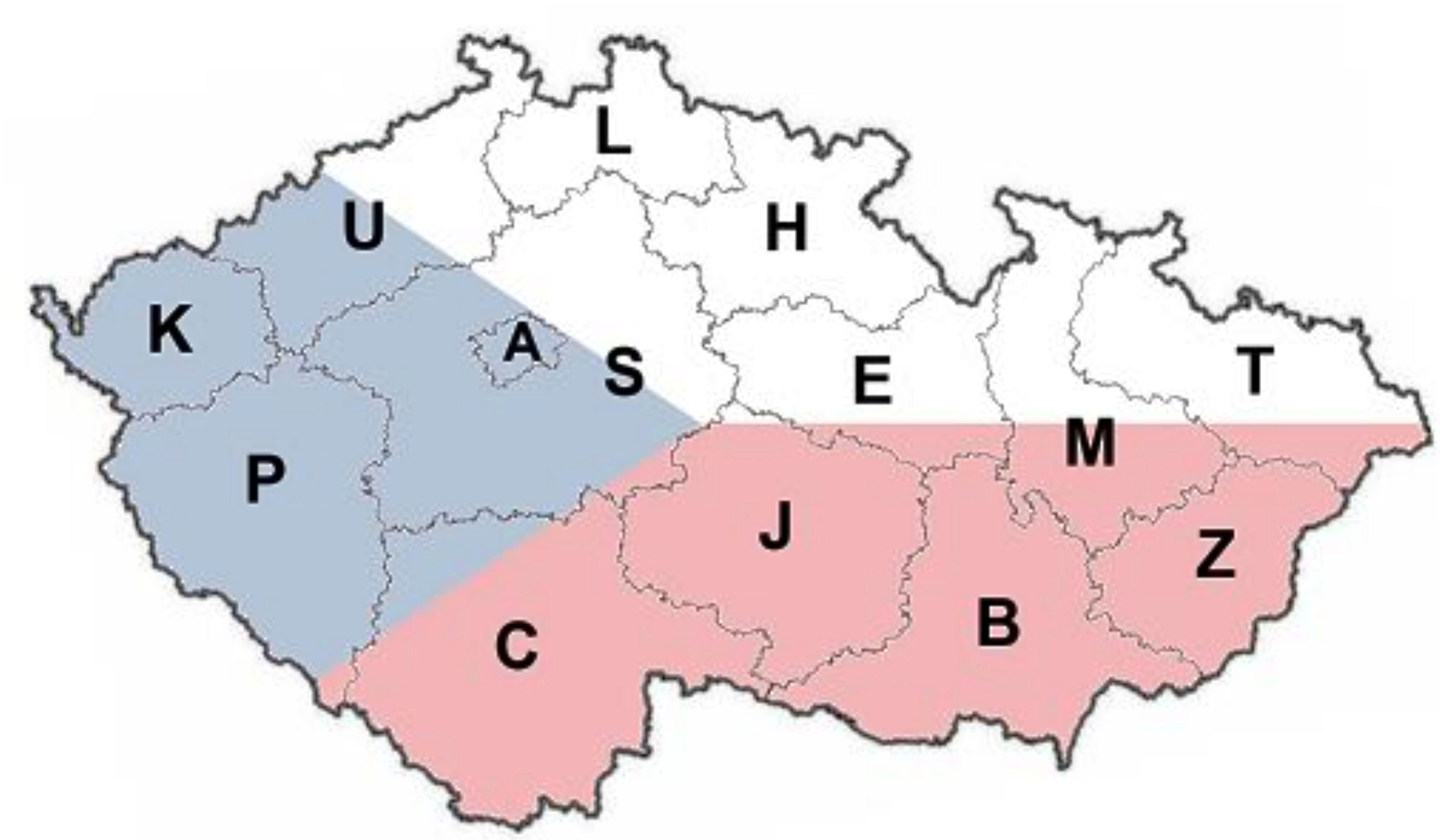
Table 1. DISH history overview.

WASTE-TO-ENERGY FACILITY PLACEMENT

Application example

Czech Republic

Czech Republic



Application

- Waste-to-Energy facilities in Czech Republic

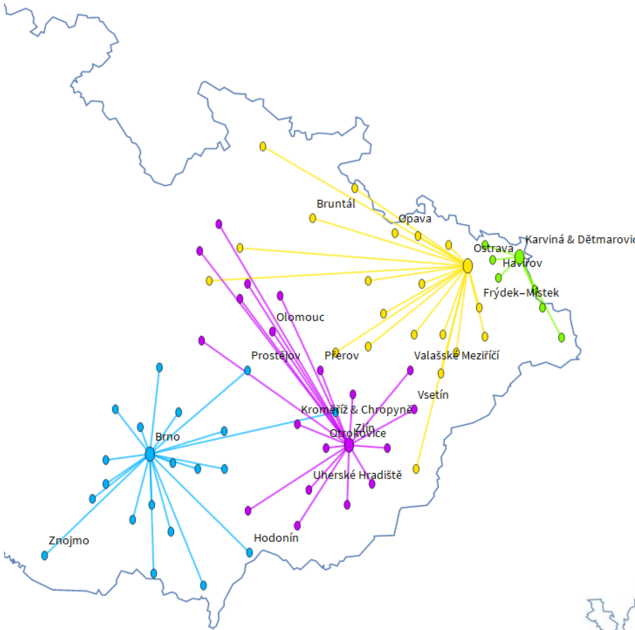
- **Waste production (2018)** **3.20** Mt
- **Used for energy recovery (~23%)** **0.75** Mt
- **The rest** landfills

- **Facility optimization (placement, capacity, producers)**
- Mixed-integer non-linear problem

Scale of the problem

- 4 existing facilities (2 ready for extension)
- 36 possible new facility locations
- Each facility has from 2 to 27 various options for its capacity
- 204 waste producers
- Non-linear penalization for unused capacity

Facility placement – example solutions



Solved by DR_DISH algorithm

4 regions

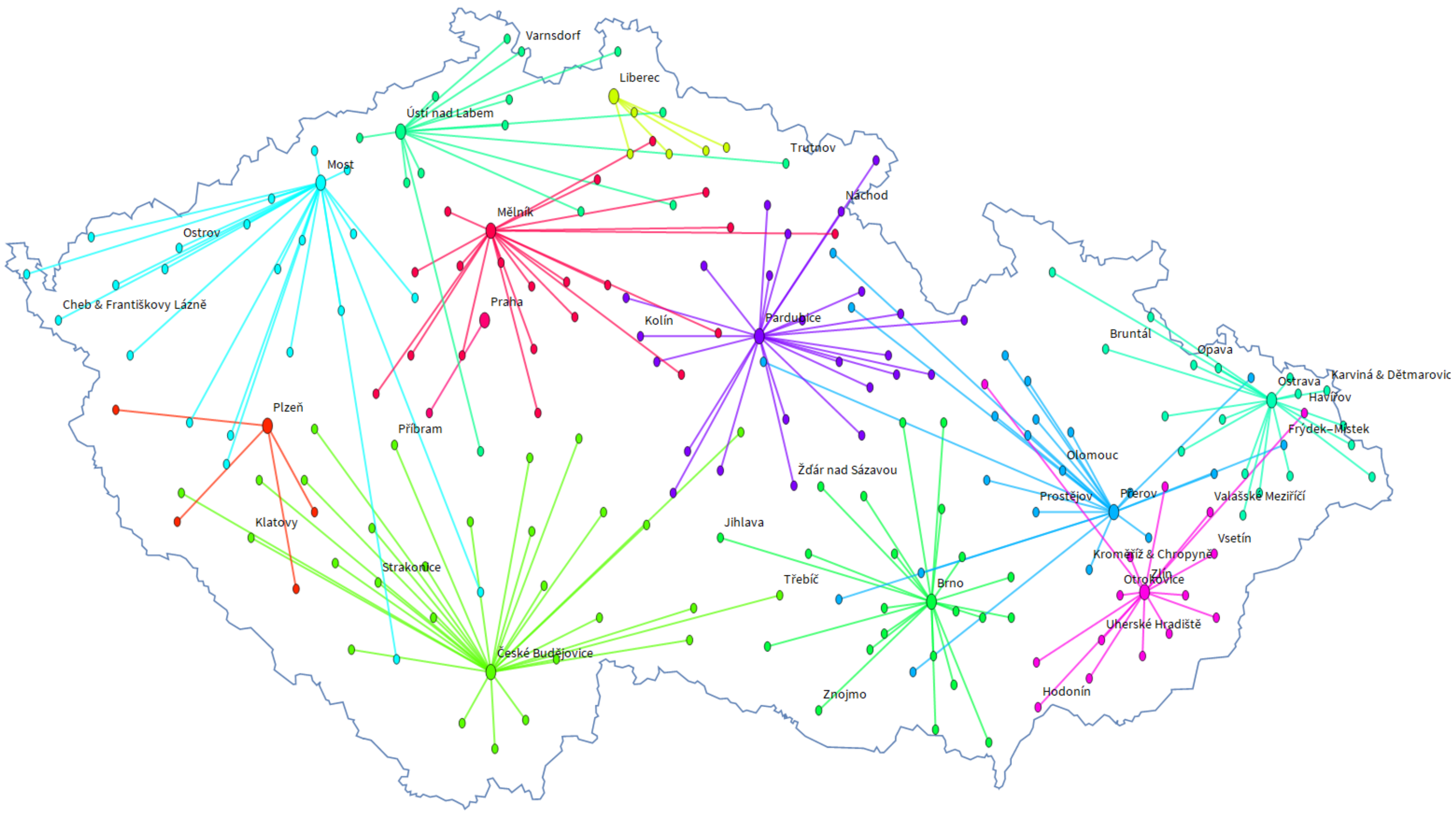
9 regions

Comparison to conventional solver

Nr. of regions	Objective function value [EUR]			Computing time [h:mm:ss]		Nr. of fac. [-]	
	DICOPT	DR_DISH	Diff. [%]	DICOPT	DR_DISH	DICOPT	DR_DISH
1	2.10E+07	2.10E+07	0	0:00:04	0:01:48	1	1
4	9.45E+07	1.02E+07	7.94	0:01:15	0:08:22	9	4
5	1.06E+08	1.11E+08	4.72	0:01:39	0:09:46	6	4
8	1.60E+08	1.62E+08	1.25	3:55:32	0:17:09	12	6
9	2.11E+08	2.12E+08	0.47	5:54:08	0:22:21	14	8
10	-	2.42E+08	-		0:23:44	-	9
14	-	3.02E+08	-		0:40:53	-	12

Table 2. Result comparison between conventional optimizer (DICOPT) and metaheuristic optimizer (DR_DISH).

Solution for the whole Czech Republic



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THANK YOU

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