Cooperative Coevolutionary Invasive Weed Optimization and its Application to Nash Equilibrium Search in Electricity Markets

H. Hajimirsadeghi, A. Ghazanfari, A. Rahimi Kian, C. Lucas

Control and Intelligent Processing Center of Excellence

University of Tehran, Iran

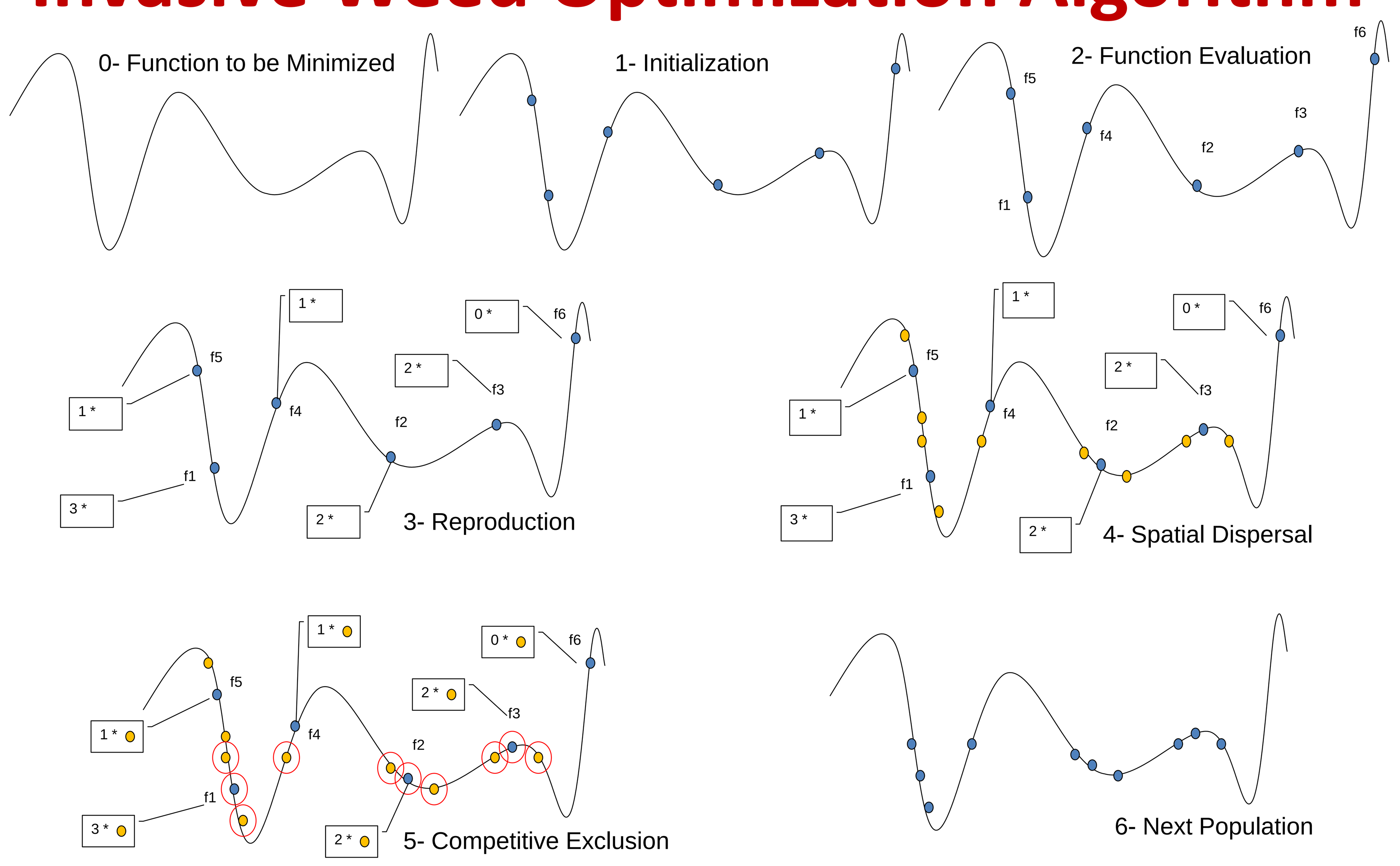
Philosophy

- Why Weeds?
  - The most robust and troublous plant in agriculture.
  - After thousands of tillage and hand-weeding we still have weeds.
  - After 50 years of herbicides we still have weeds.
- Why Coevolutionary Computing:
  - Task decomposition
  - Parallel computation
  - Simulation of multiagent systems

Motivation

- IWO improves search capability in Coevolutionary Algorithms
- Coevolutionary framework prepares a suitable basin for parallel computation and simulation of multiagent systems (like markets)

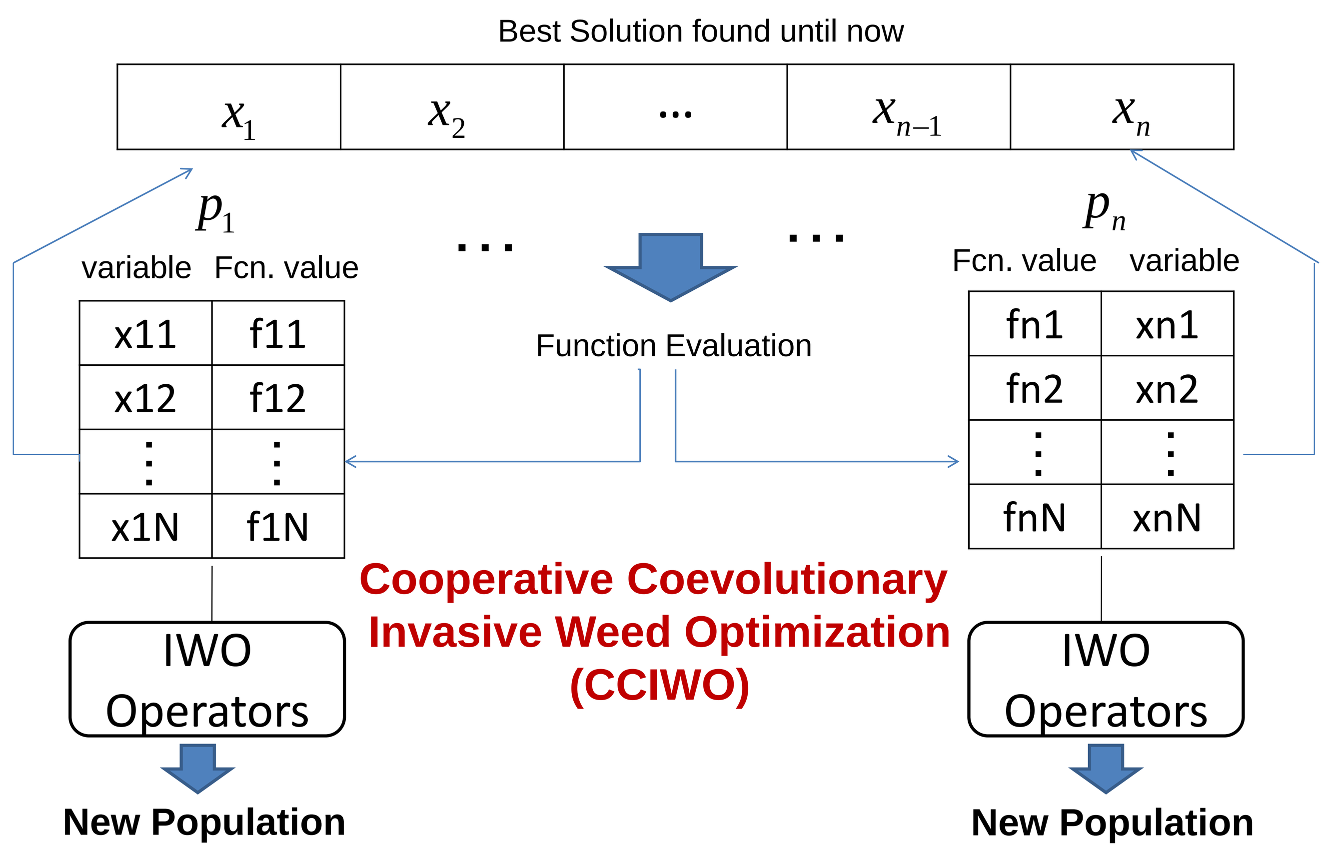
Invasive Weed Optimization Algorithm



Cooperative Coevolutionary Algorithm

- General Cooperative Coevolutionray Algorithm

1. For population $p_s \in P$, all populations
   a. Initialize population p_s ;
2. For population $p_s \in P$, all populations
   a. Evaluate population p_s with collaborators;
3. For $t = 0$ until a terminating criterion is met
   a. For population $p_s \in P$, all populations
      i. Evolutionary process to make next generation;
      ii. Evaluate next generation with collaborators;
4. Next t



Cooperative Coevolutionary Invasive Weed Optimization (CCIWO)

Results of CCIWO for Function Optimization

Name	Function	Initial range	Modality
Sphere	$\sum_{i=1}^{n}(x_i^2)$	[-100, 100]	unimodal
Rosenbrock	$\sum_{i=1}^{n}[100(x_{i+1}-x_i^2)^2+(x_i-1)^2]$	[-2.12, 2.12]	unimodal
Rastrigin	$\sum_{i=1}^{n}(x_i^2-10\cos(2\pi x_i)+10)$	[-5.12, 5.12]	multimodal
Ackley	$-20\exp(-0.2\sqrt{\frac{1}{n}\sum_{i=1}^{n}x_i^2})-\exp(\frac{1}{n}\sum_{i=1}^{n}\cos(2\pi x_i))+20+e$	[-32, 32]	multimodal
Griewank	$1+\sum_{i=1}^{n}(\frac{x_i^2}{4000})-\prod_{i=1}^{n}\cos(\frac{x_i}{\sqrt{i}})$	[-600, 600]	multimodal

FUNCTION	Mean value			Number of Function Evaluation		
	CCGA	LCGA	CCIWO	CCGA	LCGA	CCIWO
Sphere	1e-08	1e-12	4e-13	600000	600000	326203
Rosenbrock	70	90	0.27	600000	600000	323635
Rastrigin	0.5	0.12	4e-10	600000	600000	324578
Ackley	0.8	8	3e-07	600000	600000	316616
Griewank	0.02	2	2e-12	600000	600000	323789

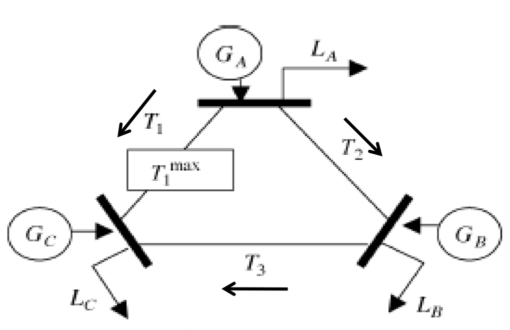
Transmission-Constrained Electricity Markets

$$\max\left\{P_i\, q_i - Cost_i \,\middle|\, \begin{array}{l}\max \sum_j Benefit_j \\ \text{St. Transmission Constraints}\end{array}\right\}$$

q_i : bidding strategy for producer i

P_i : local clearing price of market

- Three Bus Cournot Model with Linear Demand Function



$$B_1(d_1) = -0.0555d_1^2 + 108.4096d_1 \qquad C_1(q_1) = 0.00786q_1^2 + 1.3606q_1$$

$$B_1(d_1) = -0.0669d_2^2 + 103.8238d_2 \qquad C_1(q_1) = 0.010526q_1^2 - 2.07807q_1$$

$$B_1(d_1) = -0.0637d_3^2 + 108.6709d_3 \qquad C_1(q_1) = 0.006478q_1^2 + 8.105354q_1$$

Nash Equilibrium (NE)

u_i : strategy for player i $\qquad \pi_i$: payoff for player i

$\{u_1^*,\ldots,u_n^*\}$ is a Nash Equilibrium if :

$$\forall i, \forall u_i \qquad \pi_i(u_1^*,\ldots,u_i^*,u_{i+1}^*,\ldots,u_n^*) \geq \pi_i(u_1^*,\ldots,u_i,u_{i+1}^*,\ldots,u_n^*)$$

Results of NE Search with CCIWO

$\pi_i = \lambda_i^*\, q_i - C_i(q_i)$

where λ_i^* s are the lagrange multipliers of energy balance equality conditions in :

$\max_{d}(B_1(d_1)+B_2(d_2)+B_3(d_3))$

$S.T. \quad q_1 - d_1 = 2T_1 - T_3, \quad q_2 - d_2 = -T_1 + 2T_3,$

$\qquad q_3 - d_3 = -T_1 - T_3, \quad |T_1| < T_1^{max}$