CSE/ECE 848 Introduction to Evolutionary Computation

Module 3, Lecture 15, Part 3

Machine Learning Enhanced Evolutionary Computation

Kalyanmoy Deb, ECE

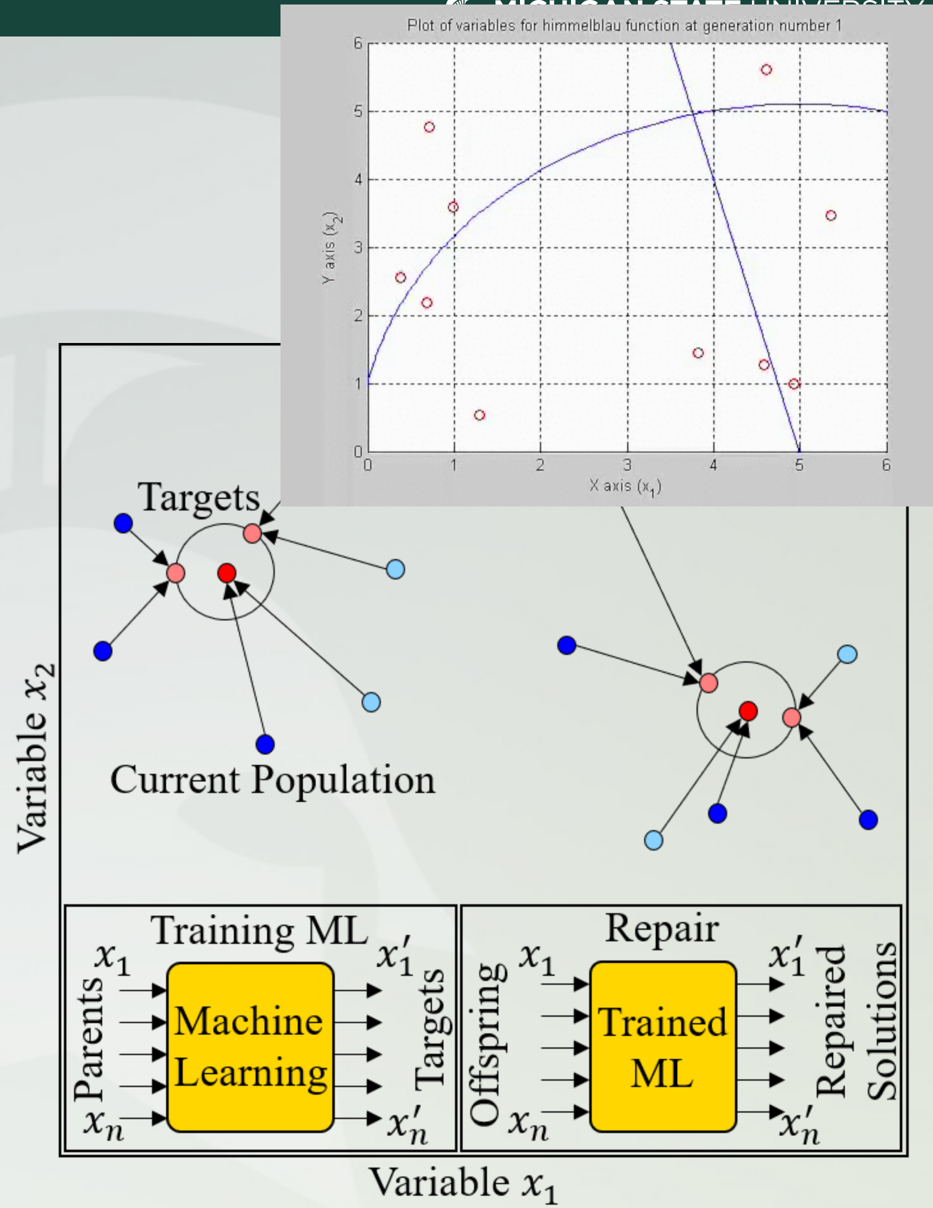
Koenig Endowed Chair Professor

Content

- Machine learning to improve EC
- Initial population generation
  - Create a uniformly distributed population in the feasible search space
- ML-augmented EC operators
  - Recombination: Find patterns in children using ML and share them with children
  - Mutation: Learn regions of less-dense region and create mutated points there or find most beneficial variable to mutate
- Introduce new operators based on ML
- Better surrogates using Auto-Encoders
- History based update operator (“Innovized” repair)

“Innovized” Repair Operator

- Targets: Current best pop members (output)
- Past clustered pop members (Input)
- Train an ANN to learn the relationship
- Apply Trained ML to repair an offspring pop member (input) to create an updated member (output)
- Apply after a few generations



Reference: K. Deb, S. Mittal, D. K. Saxena and E. Goodman (in press). Embedding a Repair Operator in Evolutionary Single and Multi-Objective Algorithms – An Exploitation-Exploration Perspective. *Proc. of Evolutionary Multi-criterion optimization* (EMO-2021). Springer.

EC with IR Operator

Algorithm 1 Generation t of EA with IR operator

Require: Parent population P_t, Archive A_t.

1: $A_t \leftarrow A_T \bigcup P_t \setminus P_{t-t_{past}}$ `% Archive Update`
2: $P_{mating} \leftarrow$ Tournament Selection on P_t
3: $Q_t \leftarrow$ Crossover and mutation on P_{mating}
4: $T \leftarrow$ Variable vector(s) of target solution(s) identified from P_t
5: $X \leftarrow$ All variable vectors in A_t
6: $D \leftarrow$ Map the solutions in X to T
7: $D \leftarrow$ Dynamic normalization of D `%using equation 1`
8: $Model \leftarrow$ Train the ANN using D
9: $Q_t \leftarrow$ Repair randomly selected 50% offsprings Q_t using $Model$
10: Evaluate Q_t
11: $P_{t+1} \leftarrow$ Survival Selection on $P_t \bigcup Q_t$
12: **return** Next Parent Population P_{t+1}

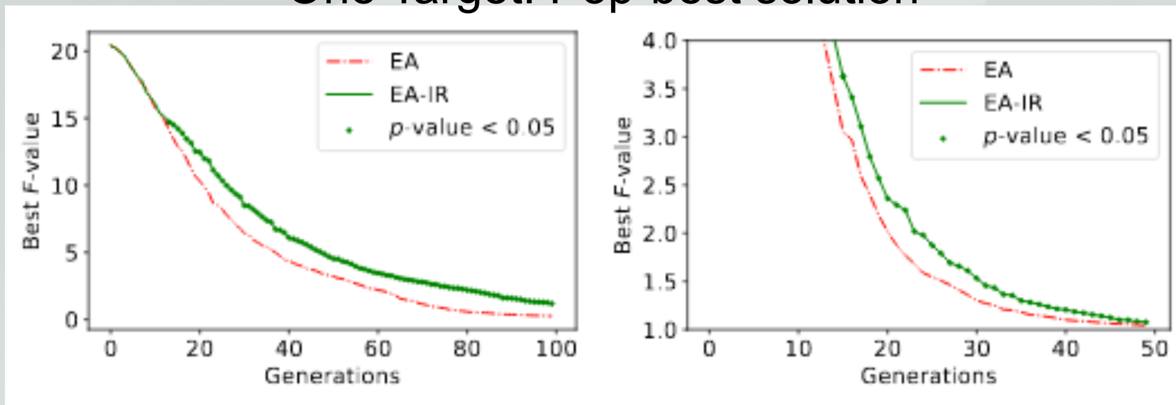
Choose Diverse solutions

$$x_k^{\min} = 0.5(x_k^{l,t} + x_k^l), \quad x_k^{\max} = 0.5(x_k^{u,t} + x_k^u).$$

EC with IR Operator Results

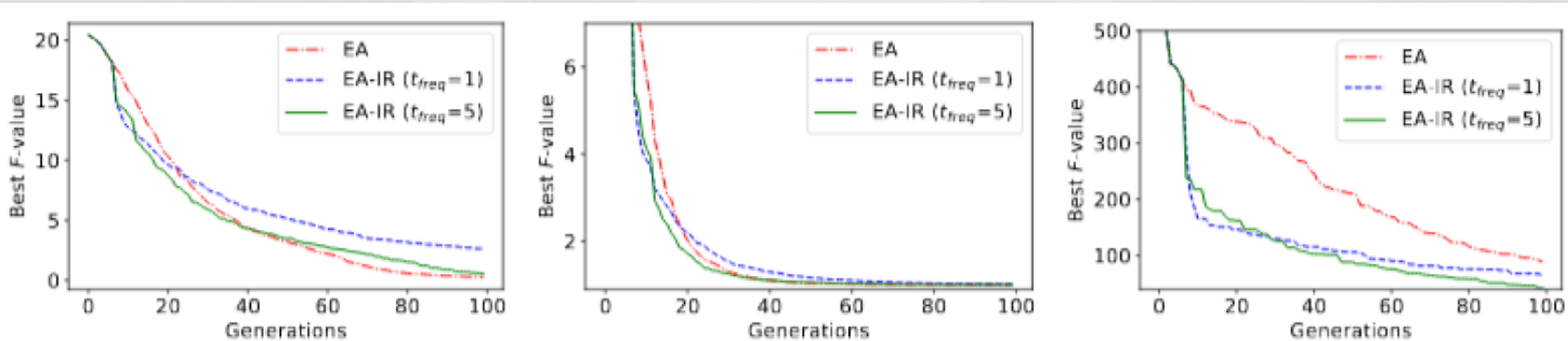
One Target: Pop-best solution

IR does not perform well



(a) Ackley (b) DPF

Multiple Targets from Population

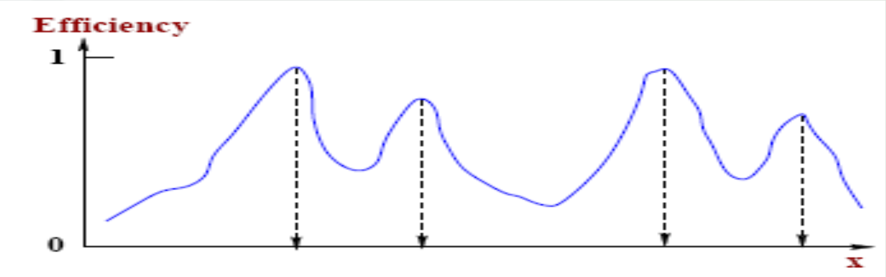


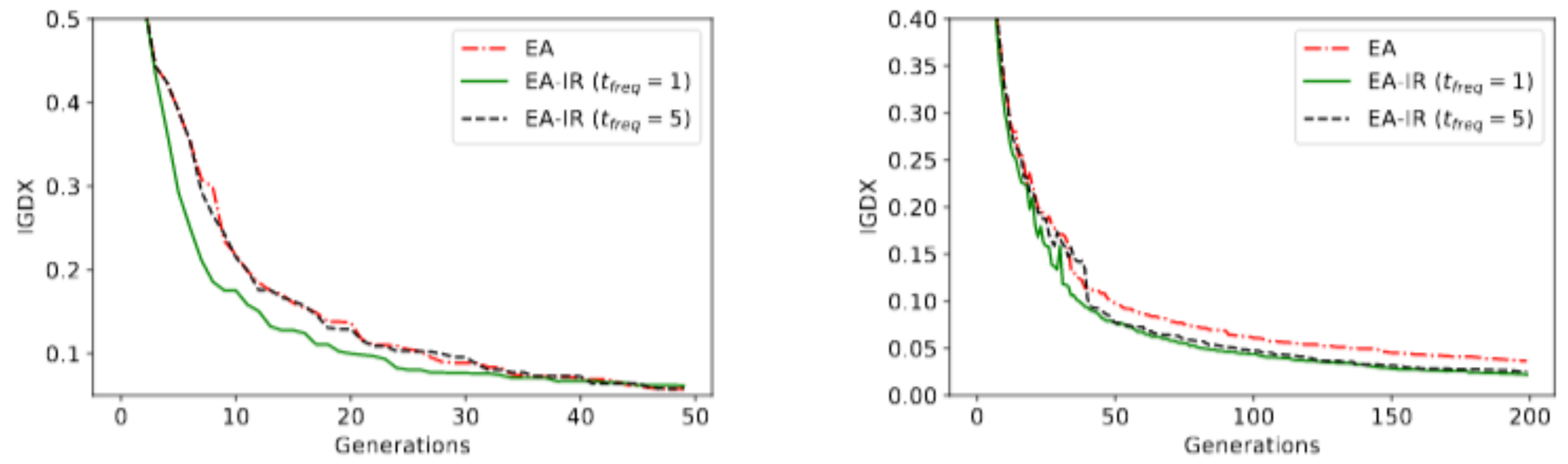
(a) Ackley (b) DPF (c) Zakharov

IR performs well

Multi-Modal Optimization

- Cluster-based identification of multiple but diverse targets (Lecture 4, Module 16, Part 3)
- Find multiple optimal solutions in one run

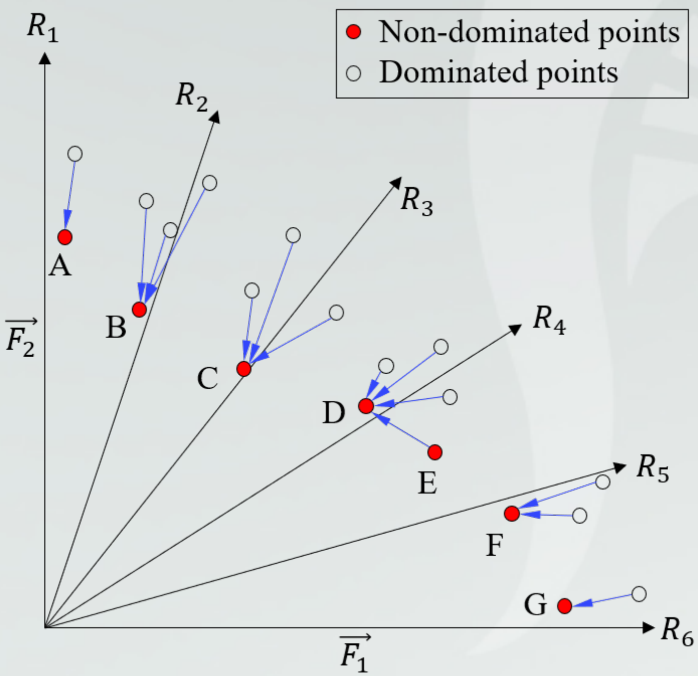


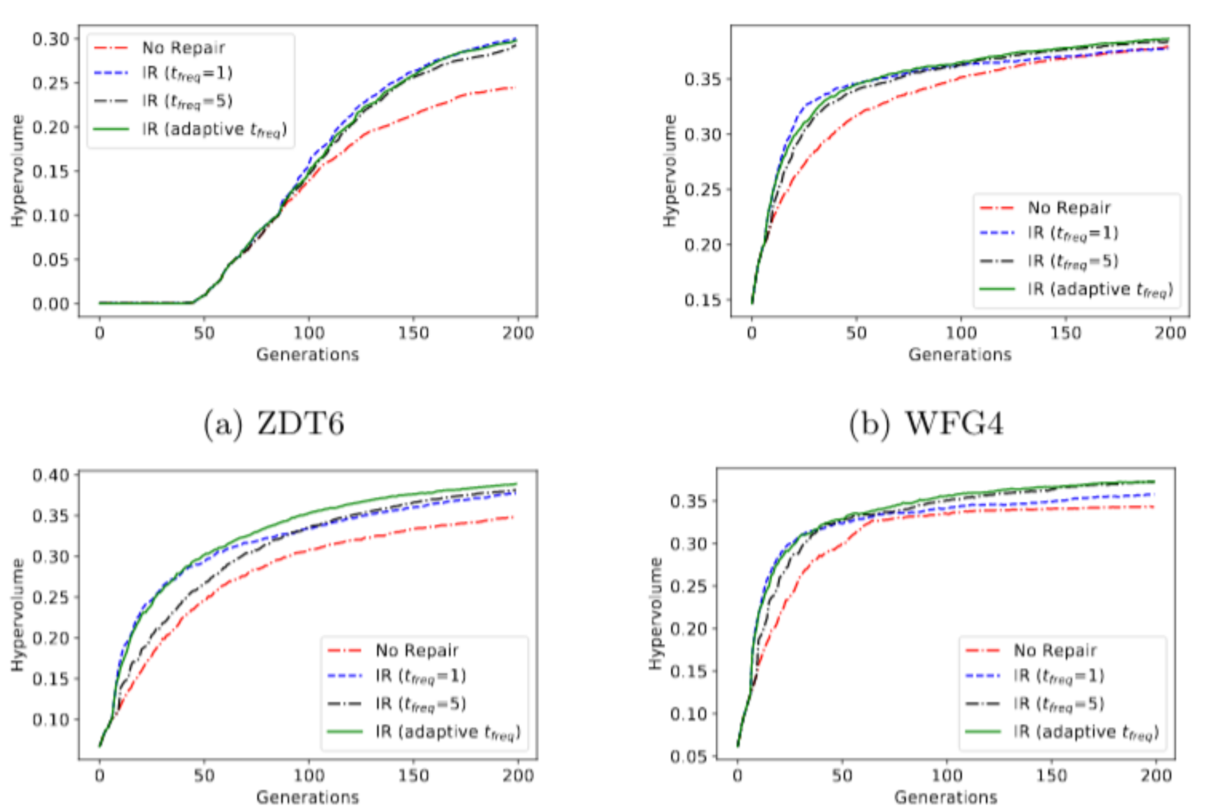


(a) Himmelblau Problem ($n = 2$)   (b) MMP Problem ($n = 15$)

Multi-Objective Optimization

- Idea applicable to multi-objective optimization (Lecture 4, Module 17, Parts 1-3)
- Multiple Targets based on reference lines





(a) ZDT6

(b) WFG4

(c) WFG6

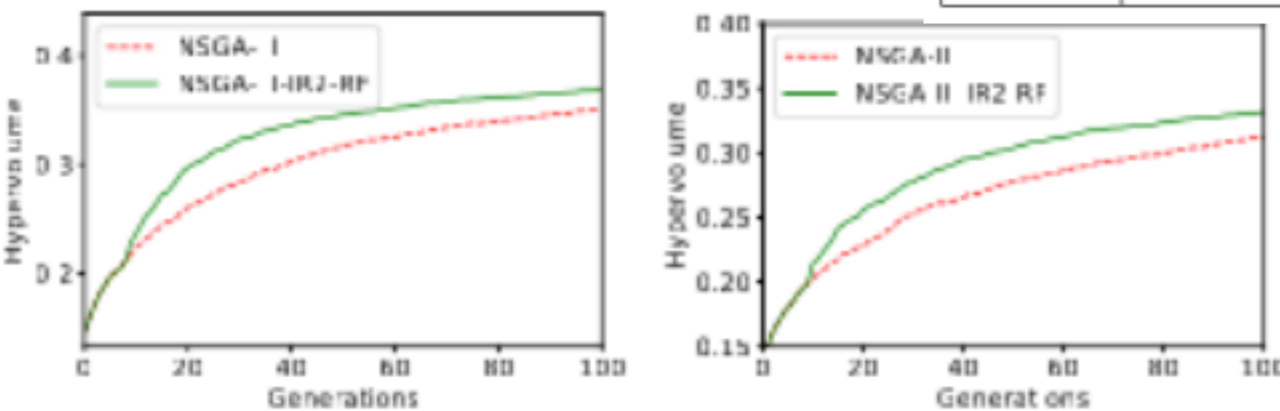
(d) WFG9

Higher Hypervolume, Better Performance

Enhanced IR with Random Forest

- ANN is replaced with RF
- IR2 is slight modification

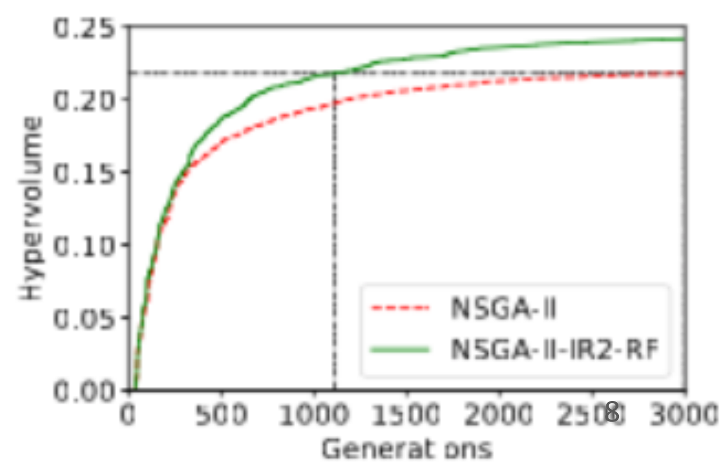
Problems	NSGA-II-IR-ANN	NSGA-II-IR-RF	*p*-value
ZDT1	0.679193	**0.680198**	8.98E-11
ZDT2	0.345448	**0.346683**	1.33E-11
ZDT3	0.535027	**0.535561**	1.62E-11
ZDT4	0.680704	**0.681041**	4.93E-04
ZDT6	**0.333949**	0.304714	1.40E-05



(a) WFG4 ($M = 3$) (b) Modified WFG4 ($M = 3$)

Gear-box Design with 28 variables, 90 constraints
63.3% Reduction in FEs

- RF performs much better than ANN
- MOEA/D's performance improves with IR2



Mittal, S., Saxena, D., **Deb, K.** and Goodman, E. (2020). *Enhanced Innovized Repair Operator for Evolutionary Multi- and Many-objective Optimization*. COIN Report No. 2020020. https://www.coin-lab.org

End of Module 3, Lecture 15, Part 3

- Machine learning methods can be used to improve performance of EC and EC's application
- Learn from past populations about progress of solutions
  - Find target solutions from current population
  - Map them with past solutions
  - Train an ML system
- Use the learned ML to update offspring created by genetic operators
- Better performance in uni-modal, multi-modal and multi-objective problems
- IR concept implemented successfully with various EC methods