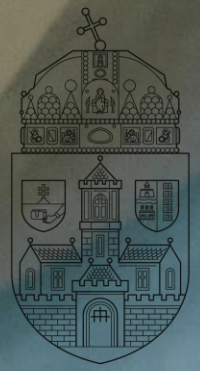


ÓBUDAI EGYETEM
ÓBUDA UNIVERSITY

EVOLUTIONARY INTELLIGENCE FOR AUTOMATED COMPUTING

Amir H Gandomi

Professor of Data Science at University of Technology Sydney
(newly) Distinguished Professor at Óbuda University

Óbuda University, Budapest
September 6, 2022

About Me!

PhD in Engineering from University of Akron, USA

320+ journal papers (>75% Q1) with H-index = 82 (32,000+ citations)

AE of several world-leading journals such as IEEE Networks and IEEE IoTJ

Mendeley analysis (led by Stanford University) ranked me as 1,279th most impactful researcher in 2020 (ranked 59th in AI and Image Processing subfield)

Ranked 17th among more than 15,000 researchers based on Genetic Programming Bibliography

Selected Membership:

- NASA - Cluster Member of *Big Data, Artificial Intelligence, Machine Learning*
- MSSANZ - Management Committee Member
- IEEE – Senior Member
- ASCE – Associate member and member of two Special Interest Committees
- XPRIZE – Alumni Hall of Fame
- Sigma Xi, The Scientific Research Honor Society – Full Member
- SEM – Life Member

More About Me!

Selected Recent Awards & Honours

2022 Walter L. Huber Civil Engineering Research Prize winner by American Society of Civil Engineers (ASCE), for “outstanding contributions to machine intelligence in civil structures and infrastructures”

Highly Cited Researcher Awards - Computer Science / Cross Field from Web of Science (2017, 2018, 2019, 2020, 2021)

2022 Obada Prize for Distinguished Scientists from Natural Sciences Publishing (NSP)

Best paper award from the IMAC XL Data Science Technical Division (ERA/CORE A) (Feb 2022)

Selected as a 2021 Consulting-Specifying Engineer 40 Under 40 award winner - CFE Media and Technology (May 2021)

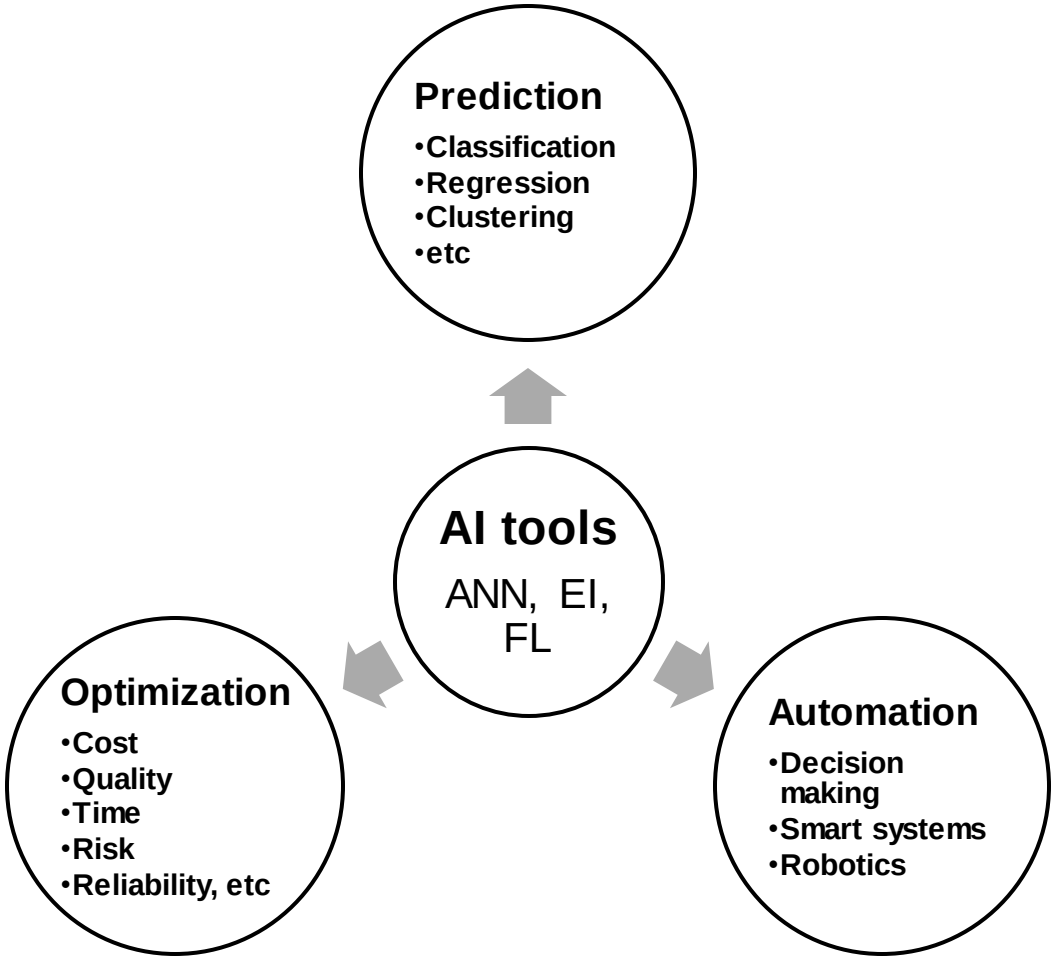
Electronics 2021 Young Investigator Award, Multidisciplinary Digital Publishing Institute, Basel, Switzerland - CHf 1,800 (April 2021)

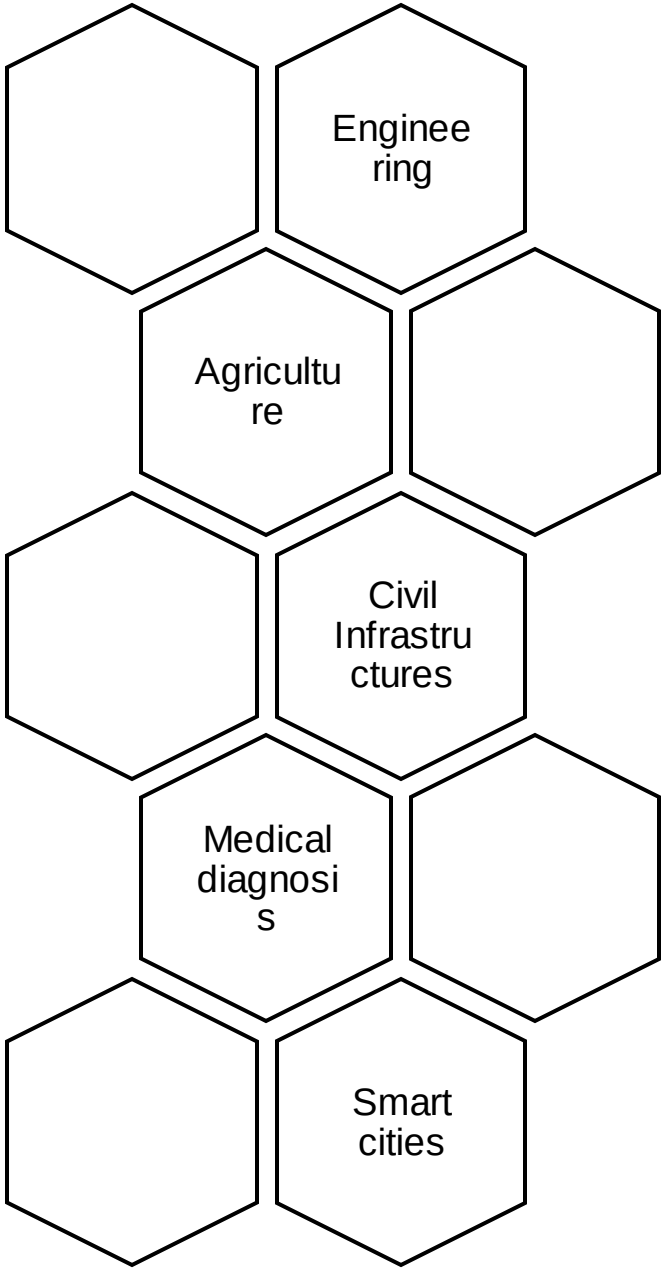
Lead a top-ten team (Kangaroos) and an Honorable Mention Winner at Pandemic Response Challenge from XPRIZE-Cognizant (March 2021)

Discovery Early Career Researcher Award (DECRA) – ARC for A$400,000 (Nov 2020)

Albert Nelson Marquis Lifetime Achievement Award (top .15%) - Marquis Who's Who (Oct 2020)

How I use AI in Action





AI for Social Good: Applications in Medical Problems (2022)

Research Articles:

- Deep CNN for leukemia classification [CBM 148, 105894, 2022]
- Precise prediction of multiple anticancer drug using ML [CMPB 224, 107027, 2022]
- Deep Learning for classifying tumor features in 3D brain slice images [CBM 149, 105990, 2022]
- Radiology imaging scans for early diagnosis of kidney tumors [BDCC 6 (1), 29, 2022]
- Deep CNN for histopathology images [CBM 149, 105943, 2022]
- Breast Cancer Diagnosis using AI [CMPB 214, 106432, 2022]
- Brain tumor big data analysis [IEEE TEM, in press]
- Early Diagnosis of Alzheimer using Neuroimaging and DL [BDCC 6 (1), 2, 2022]

Reviews:

- Machine learning in medical applications [CBM, 145, 105458, 2022]
- A review on multimodal medical image fusion [CBM, 144, 105253, 2022]

Outlines

Evolutionary Intelligence in Action

Predictive Data Analytics

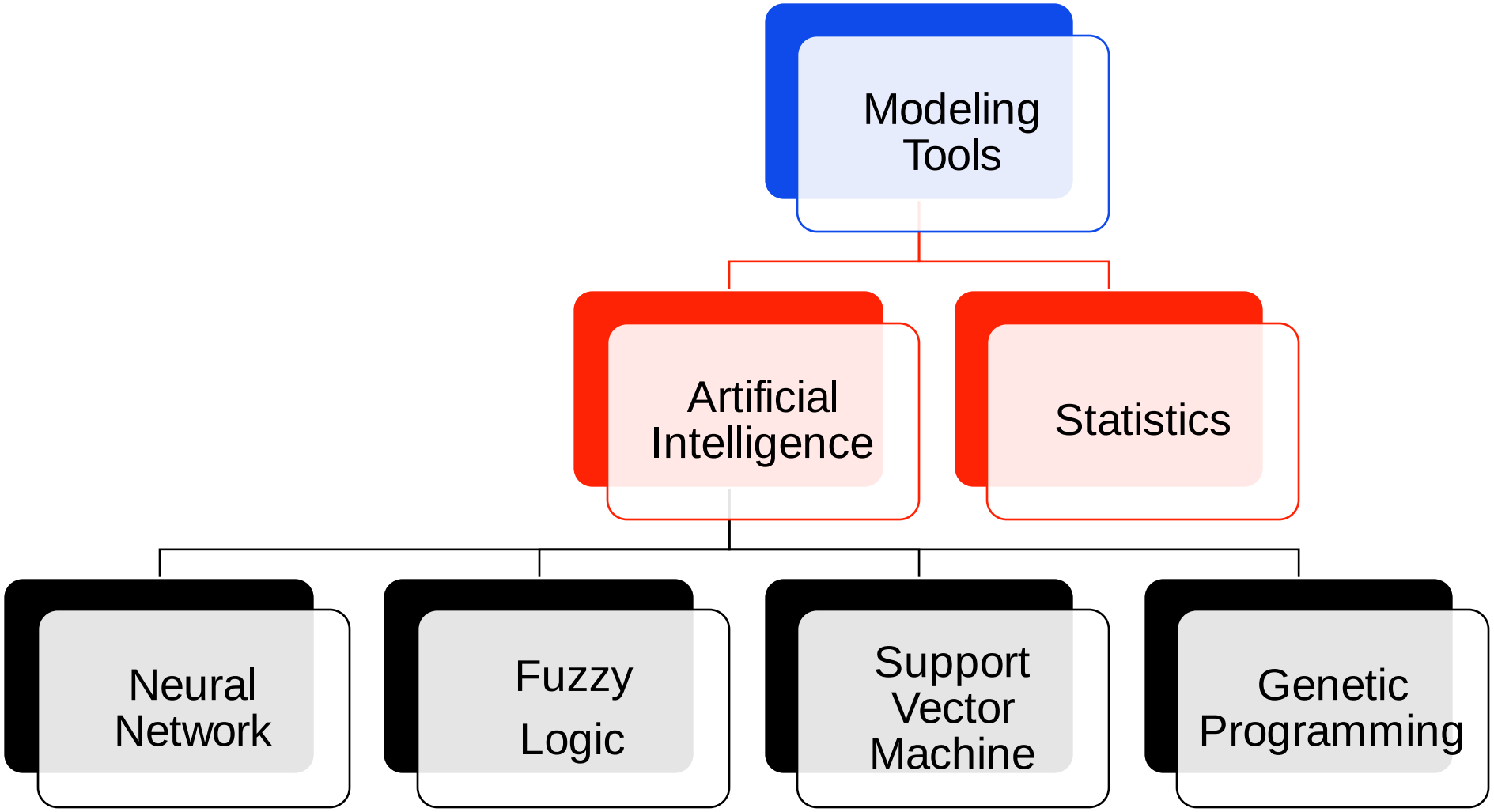
- Predictive Data Analytics
  - AI as a Predictive tool
  - Genetic Programming
    - Introduction
    - Advantages
  - GP for Big Data Analytics
    - Cutting Edge!

Optimization

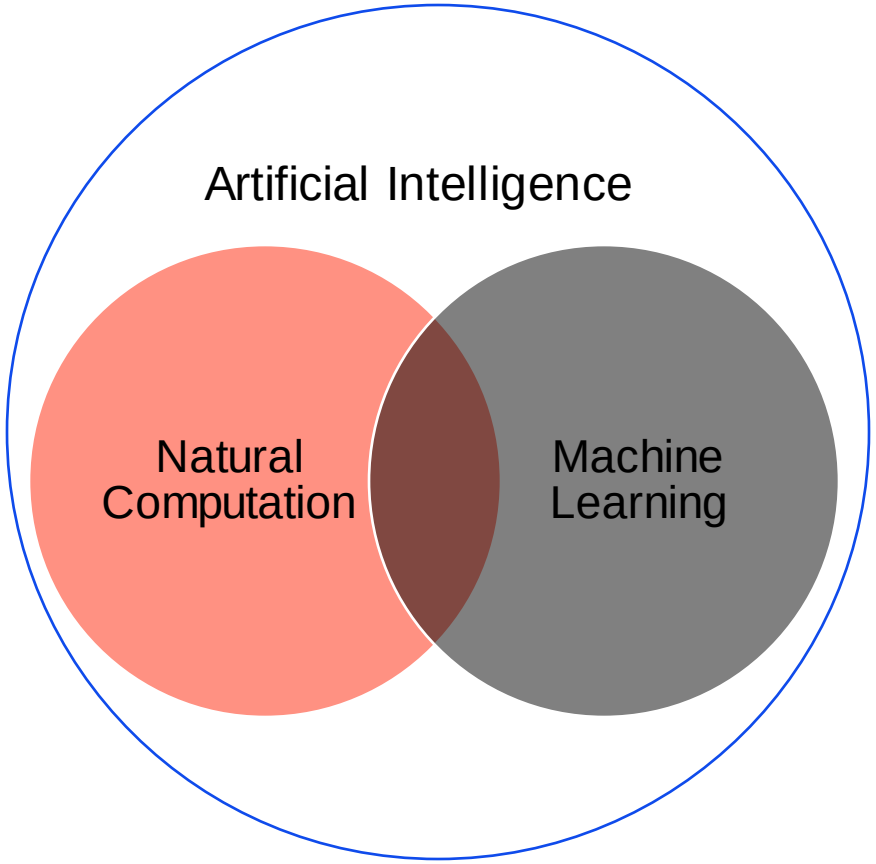
- Techniques
- Key Applications
- Domain Knowledge

AI and EI for Data Analytics

AI-based Predictive Data Analytic Tools



AI-based Predictive Data Analytic Tools



Look deep into nature, and then you will understand everything better

Albert Einstein

Nature is the source of all true knowledge.

Leonardo da Vinci

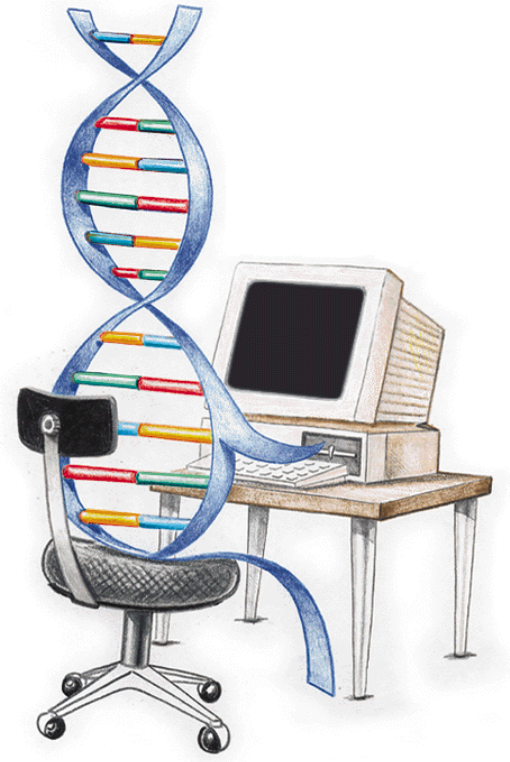
Telikani A., Tahmassebi, A.H., Banzhaf, W., Gandomi, A.H.*, “Evolutionary Machine Learning: A Survey" ACM Computing Surveys, ACM, 54(8), 11-50, 2021.

What is Genetic Programming

A Software with Evolution as the programmer!

- Many problems can be solved by genetic programing!

- Most popular for predictive data analytics

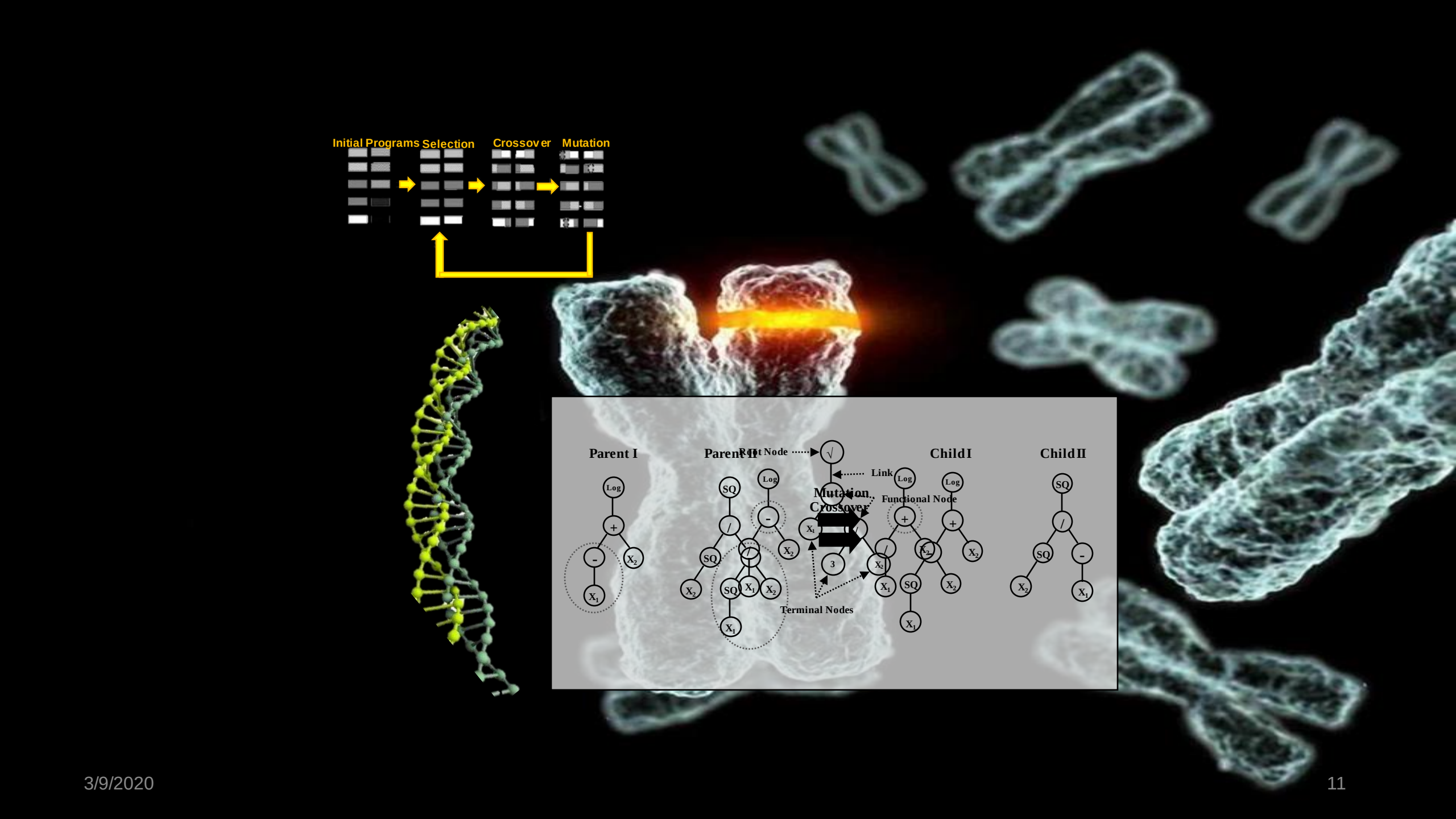


Basic Sources:

Koza, John R. (et al.) Genetic Programming I to IV

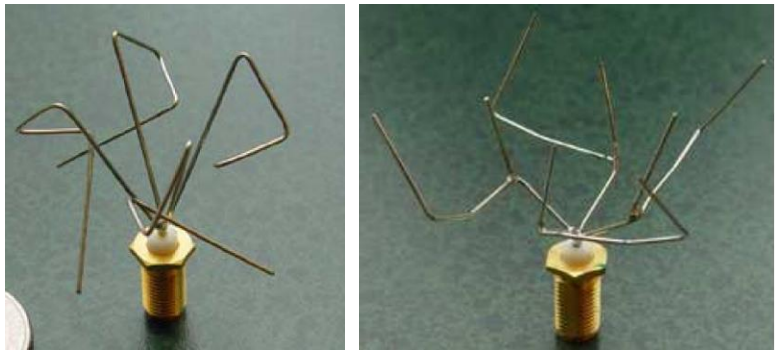
Koza, John R., and Rice, James P. 1992. Genetic Programming: The Movie. Cambridge, MA: The MIT Press.

http://www.genetic-programming.org/


Initial Programs
Selection
Crossover
Mutation
Parent I
Parent II
Root Node
Link
Functional Node
Mutation
Crossover
Terminal Nodes
Child I
Child II

Finding the Model Structure

NASA Communication antennas
On the ST-5 mission (2006)

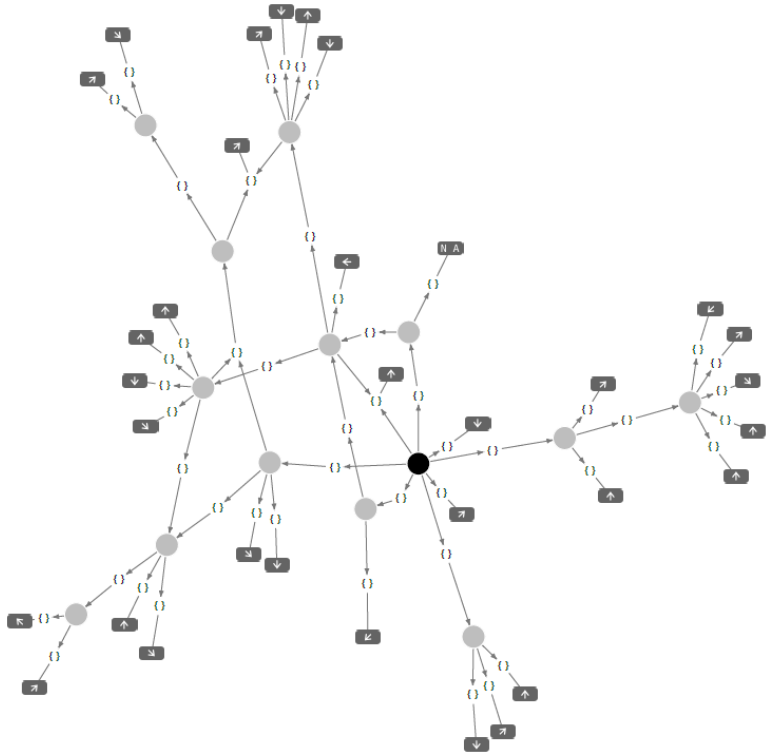


Jason D. Lohn, Gregory S. Hornby and Derek S. Linden, “Human-competitive evolved antennas”, Artificial Intelligence for Engineering Design, Analysis and Manufacturing, volume 22, issue 3, pages 235–247 (2008).

In Genetic Programming:

- The Structure is found via Evolution
- Pre-defined structure is not required
- Distinguished feature from other machine learning methods
- It can model the behaviour without any prior assumptions

Simplicity and Explainability



Kelly, Stephen, and Malcolm I. Heywood. "Emergent tangled graph representations for Atari game playing agents." In European Conference on Genetic Programming, pp. 64-79. Springer, Cham, 2017.

MIT Technology Review

Intelligent Machines

Evolutionary algorithm outperforms deep-learning machines at video games

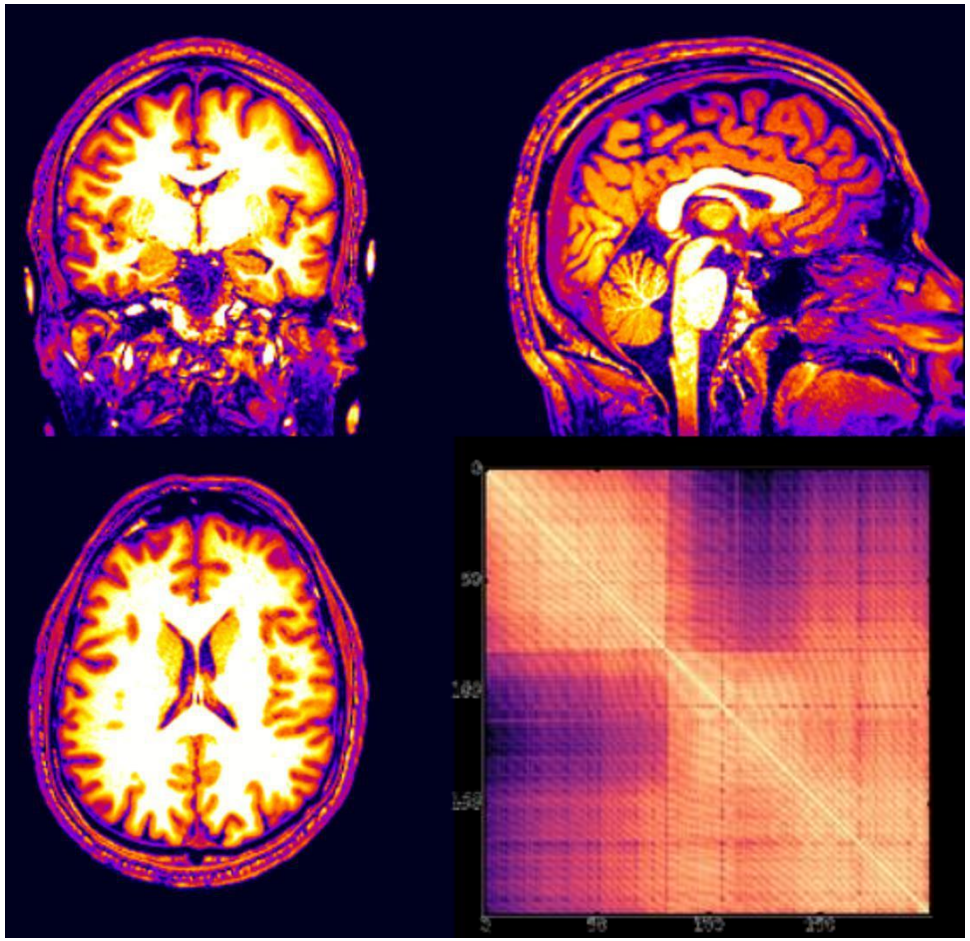
Neural networks have garnered all the headlines, but a much more powerful approach is waiting in the wings.

by Emerging Technology from the arXiv July 18, 2018

With all the excitement over neural networks and deep-learning

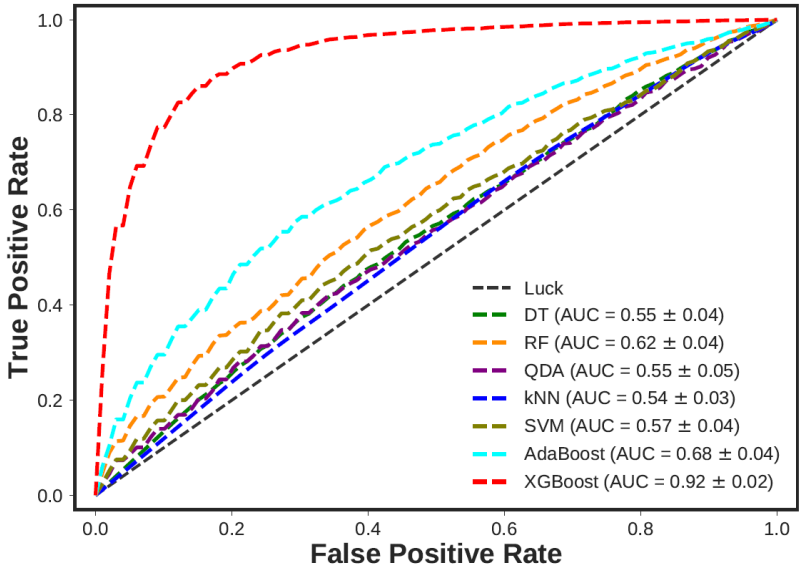
Wilson, D. G., Cussat-Blanc, S., Luga, H., and Miller, J. F. Evolving simple programs for playing atari games. In Proceedings of the Genetic and Evolutionary Computation Conference. ACM, (2018).

Inherently Making the Selections!



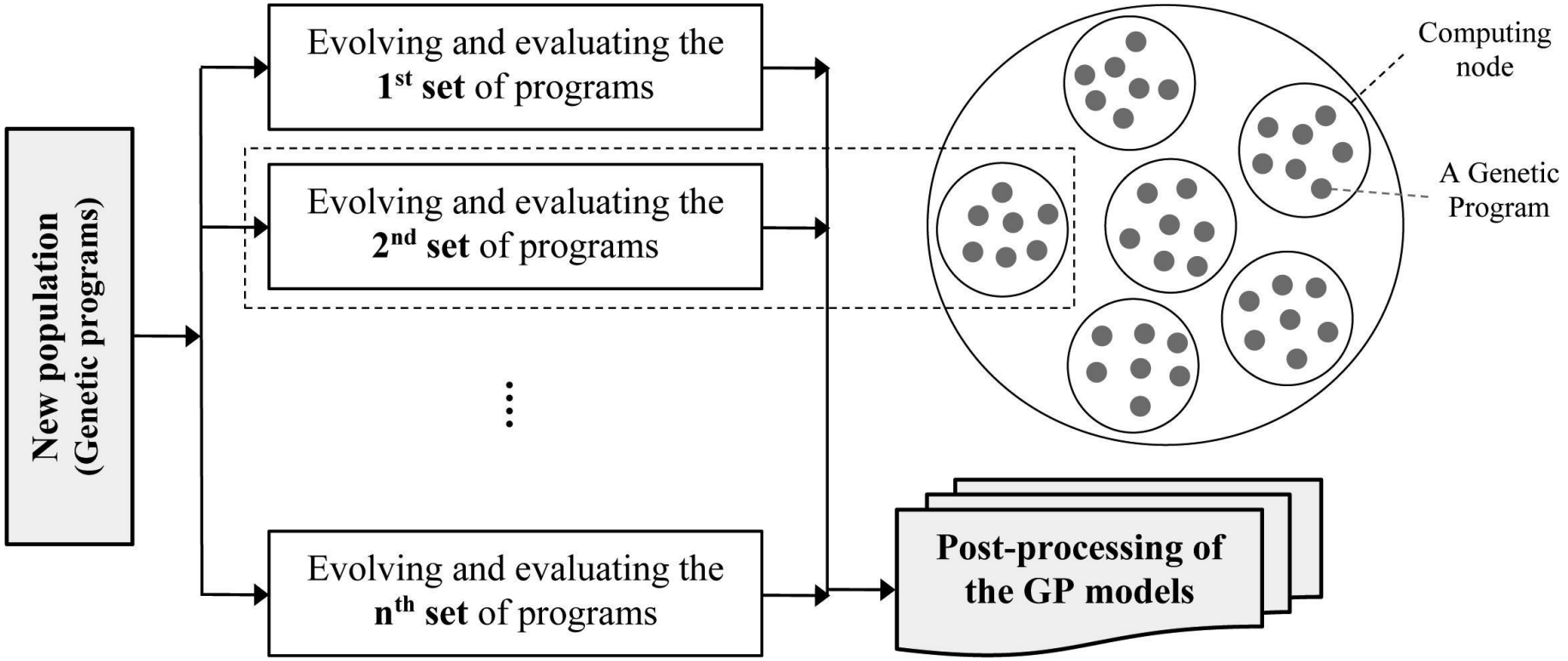
After cleaning data

- Feature selection
- Model selection



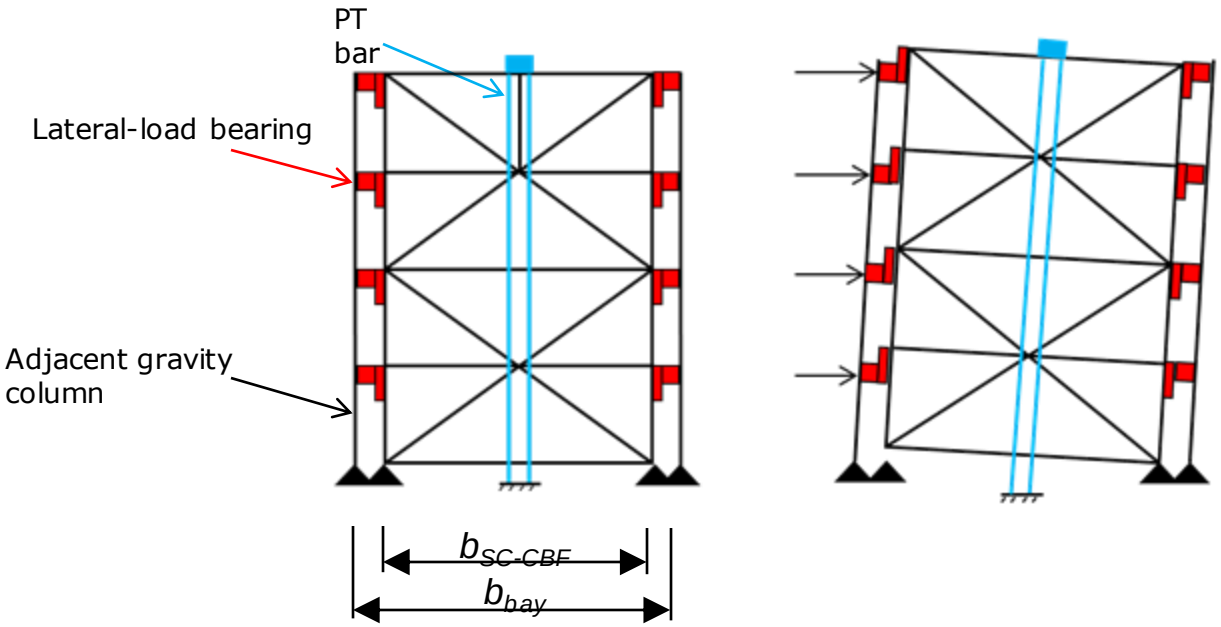
Tahmassebi, A. Gandomi A.H., et al. (2018) "Deep Learning in Medical Imaging: fMRI Big Data Analysis via Convolutional Neural Networks" Proceedings of the 2nd International Conference on Medical and Health Informatics, ACM.

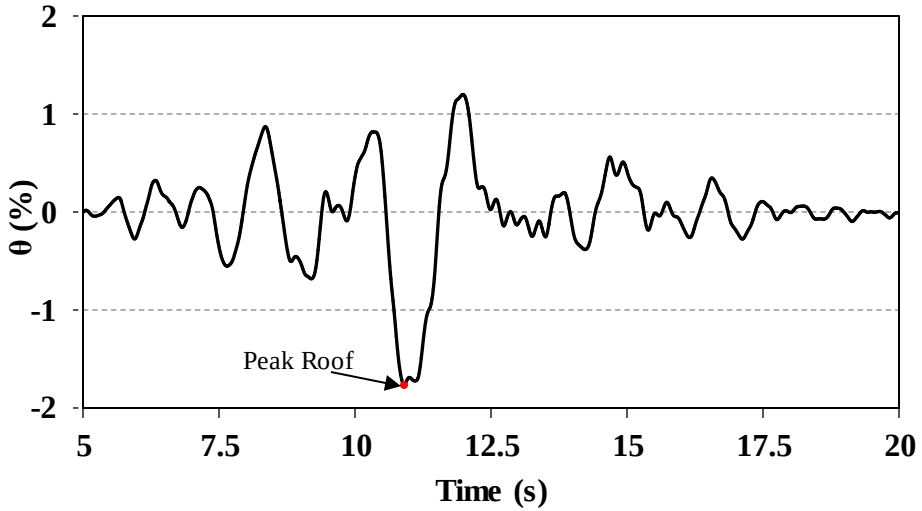
Parallel Processing in Genetic Programming



Gharehbaghi, S., Gandomi, M., Plevris, V. and Gandomi, A.H., 2021. Prediction of seismic damage spectra using computational intelligence methods. Computers & Structures, 253, p.106584.

Ex. I.1: Response of Self-Centering Concentrically Braced Frames





Gandomi A.H., "Seismic Response Formulation of Self-Centering Concentrically Braced Frames Using Genetic Programming" 2014 IEEE Symposium on Computational Intelligence, Orlando, FL, December 9-12, 2014.

Feature Selection: Evolutionary Coefficient

- Best correlation coefficient (R)!
- R: linear relationship

$$R_e = \frac{\sum_{i=1}^{n}\left(y_i - \overline{y_i}\right)\left(f_{j,GP}\left(x_{ij}\right) - \overline{f_{j,GP}\left(x_{ij}\right)}\right)}{\sqrt{\sum_{i=1}^{n}\left(y_i - \overline{y_i}\right)^2 \sum_{i=1}^{n}\left(f_{j,GP}\left(x_{ij}\right) - \overline{f_{j,GP}\left(x_{ij}\right)}\right)^2}}$$

- $f_{j,GP}$: Transformed and correlated x_j

Gandomi A.H., "Seismic Response Formulation of Self-Centering Concentrically Braced Frames Using Genetic Programming" 2014 IEEE Symposium on Computational Intelligence, Orlando, FL, December 9-12, 2014.

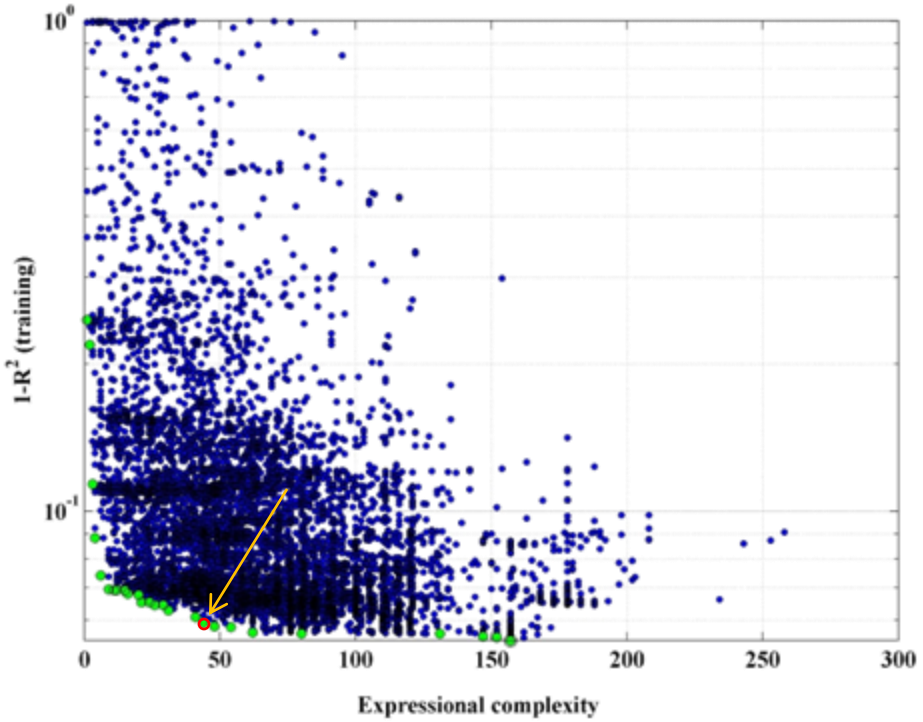
Feature Selection: Evolutionary Coefficient

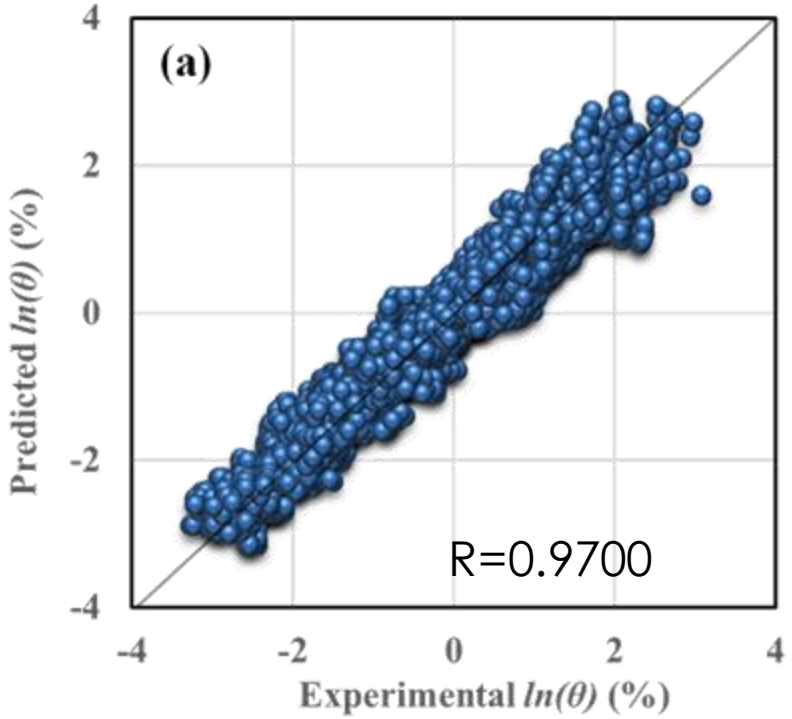
IM	Symbol	R^2	R_e^2	↑ (%)	Rank
Elastic spectral acceleration	$S_a(T)$	0.5589	0.7975	42.7	3
Elastic spectral acceleration	$S_a(2T)$	0.6709	0.8680	29.4	2
Elastic spectral velocity	S_v	0.5560	0.7938	42.8	4
Elastic spectral displacement	S_d	0.5147	0.7761	50.8	5
Peak ground acceleration	PGA	0.4190	0.5359	27.9	10
Peak ground velocity	PGV	0.7765	0.9022	16.2	1
Peak ground displacement	PGD	0.5181	0.7222	39.4	6
Cumulative absolute velocity	CAV	0.1890	0.5694	201.3	11
Cumulative absolute displacement	CAD	0.4036	0.6729	66.7	7
Arias intensity	I_A	0.1461	0.6612	352.6	8
Velocity intensity	I_v	0.4233	0.6454	52.5	9
Root mean square acceleration	A_{rms}	0.2858	0.3235	13.2	13
Characteristic intensity	I_c	0.2053	0.3305	61.0	12
Strong ground motion duration	T_D	0.0216	0.0881	307.9	14

Formulation of each Record's Response

Multi-Objective Strategy

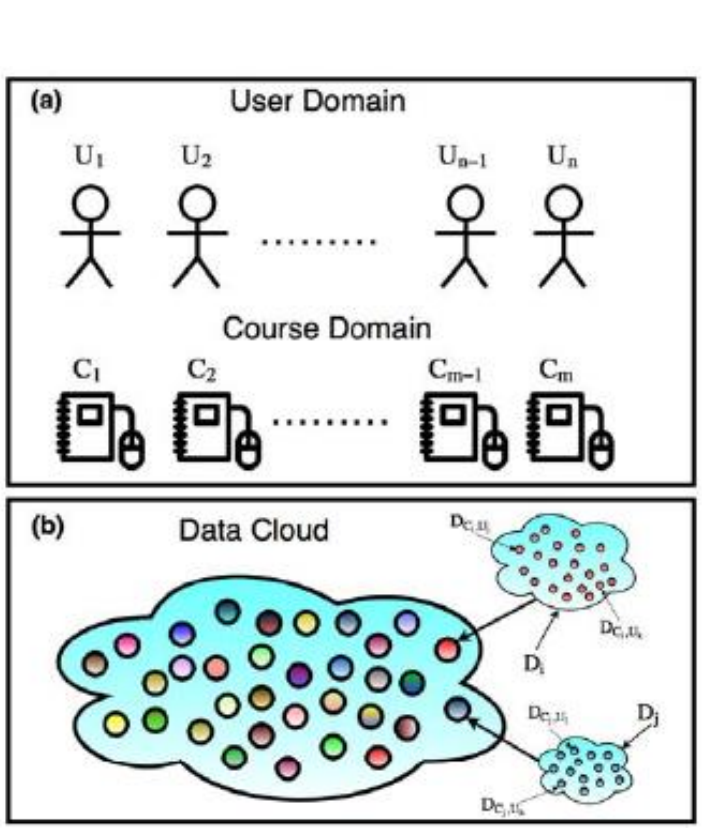
$$Ln(\theta) = 25.9PGV + 0.615\ln\left|\tanh\left(2S_a(T)\right)\left(S_a(2T) + \left(\frac{h}{b}\right)^2\right)\sqrt{F_y}\right| - 1.08$$

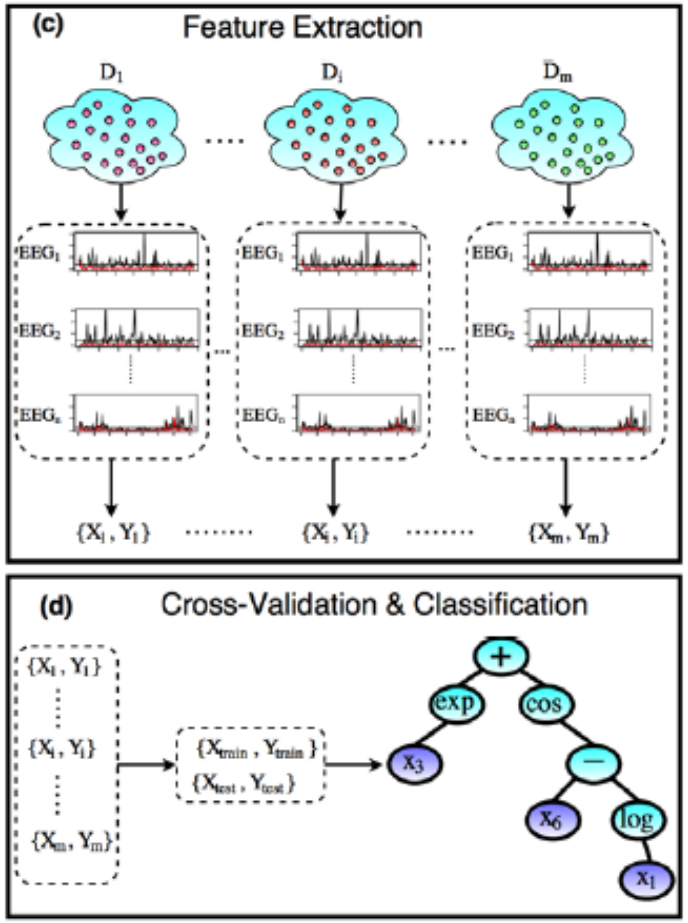


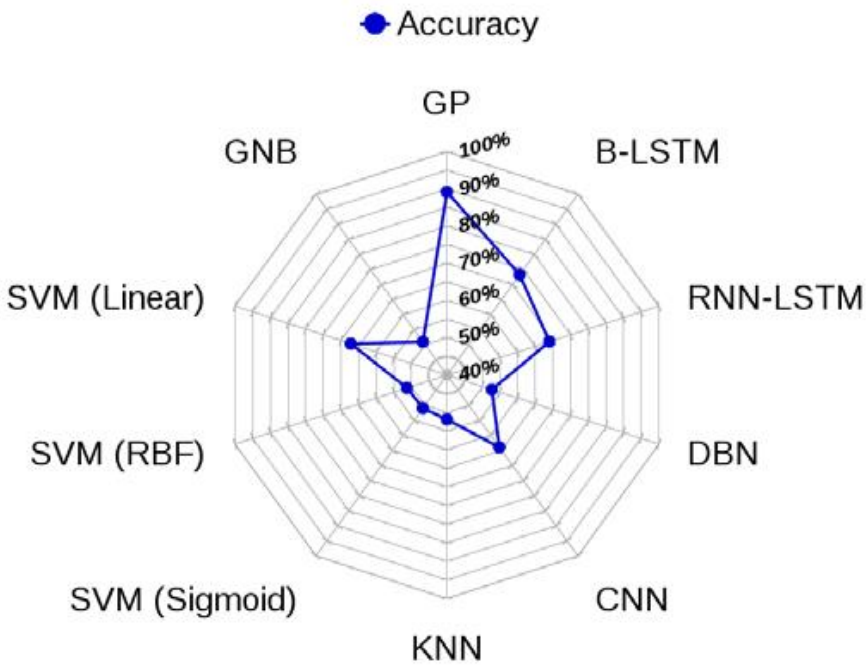


Gandomi, Amir H., and David Roke. "A Multi-Objective Evolutionary Framework for Formulation of Nonlinear Structural Systems." *IEEE Transactions on Industrial Informatics,* 18 (9), 5795 – 5803, 2022.

MOOC Performance Modelling using EEG Data

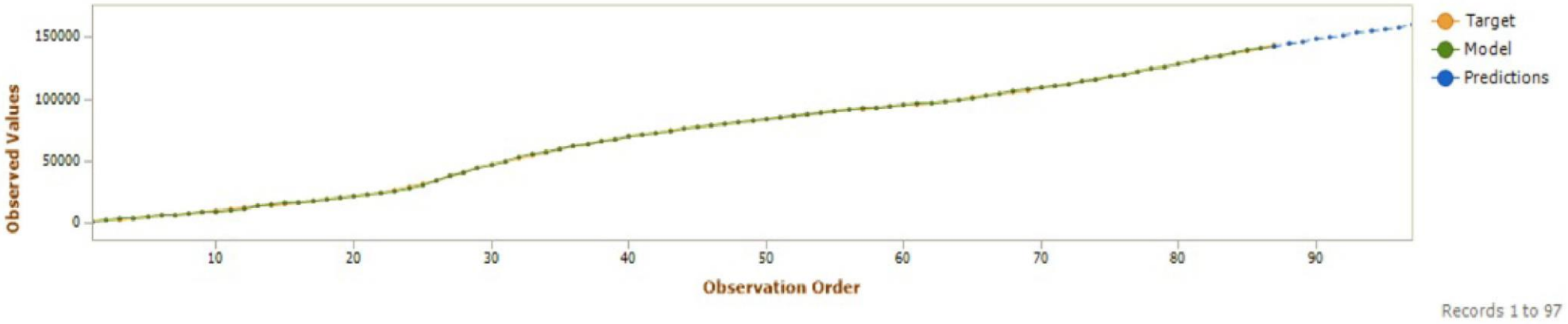




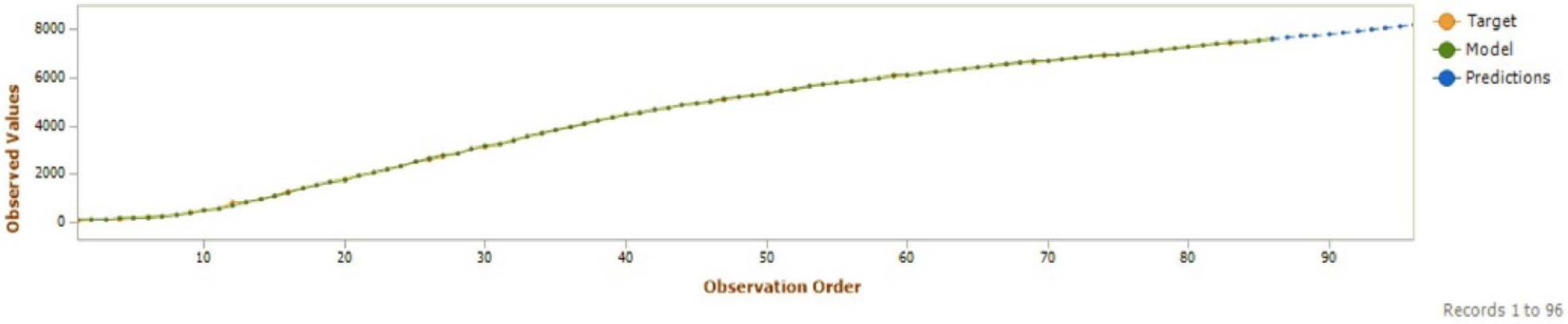


Tahmassebi, Amirhessam, Amir H. Gandomi, and Anke Meyer-Baese. "An Evolutionary Online Framework for MOOC Performance Using EEG Data." In 2018 IEEE Congress on Evolutionary Computation (CEC), pp. 1-8. IEEE, 2018.

COVID-19 Prediction and Analysis in the 15 Most affected Countries



(a) Confirmed Cases

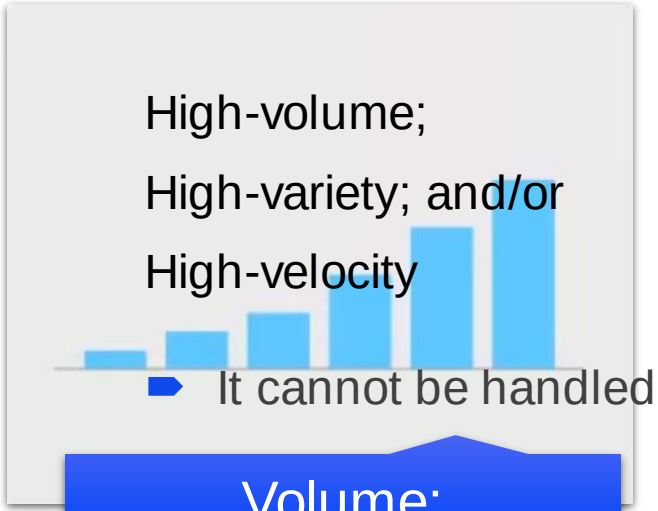


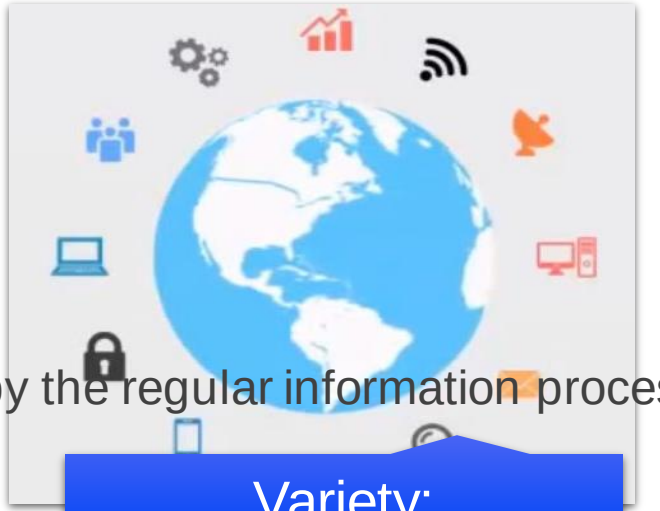
(b) Death Cases

Salgotra, R., Gandomi, M., & Gandomi, A. H. (2020). Evolutionary modelling of the COVID-19 pandemic in fifteen most affected countries. *Chaos, Solitons & Fractals*, 110118.

BIG DATA

3Vs





- It cannot be handled by the regular information processing
- Big data techniques: cost-effective and innovative

Volume: Size

Variety: Complexity

Velocity: Rate of growth

Why BIG DATA?

How much data?

>200 million

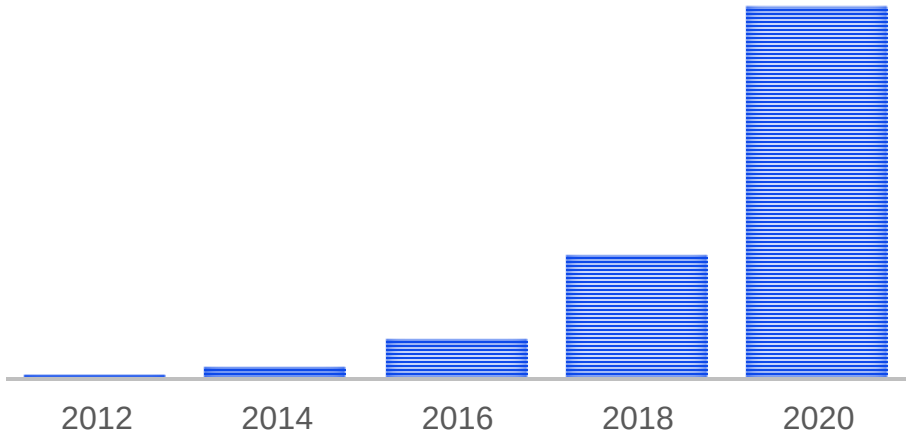
4 million

350,000

3.8 million

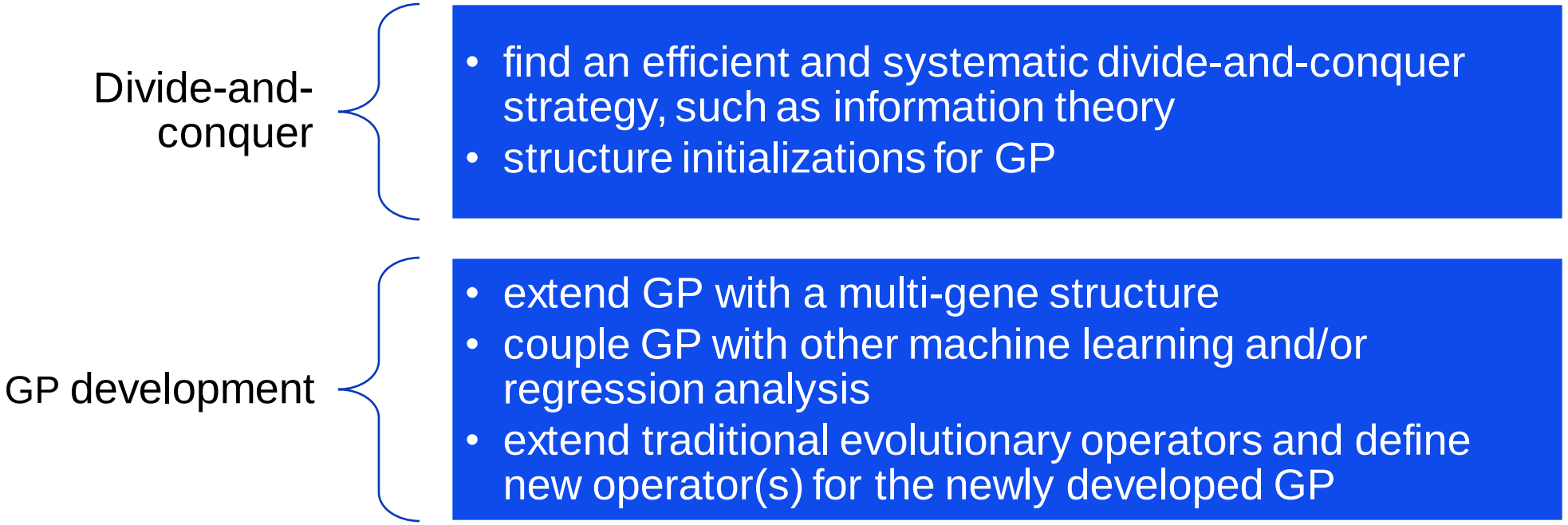
500 hours

Moore's law

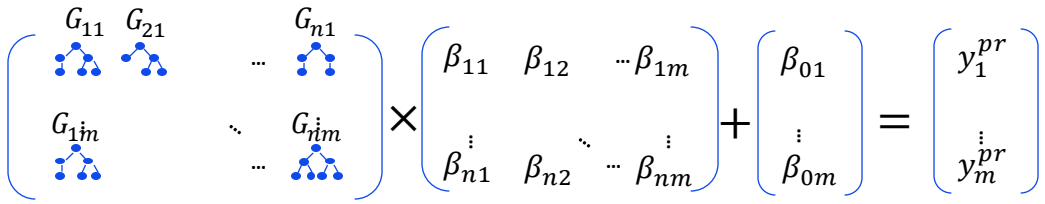


https://skai.io, https://www.brandwatch.com, https://www.dsayce.com, https://prosperitymedia.com.au/

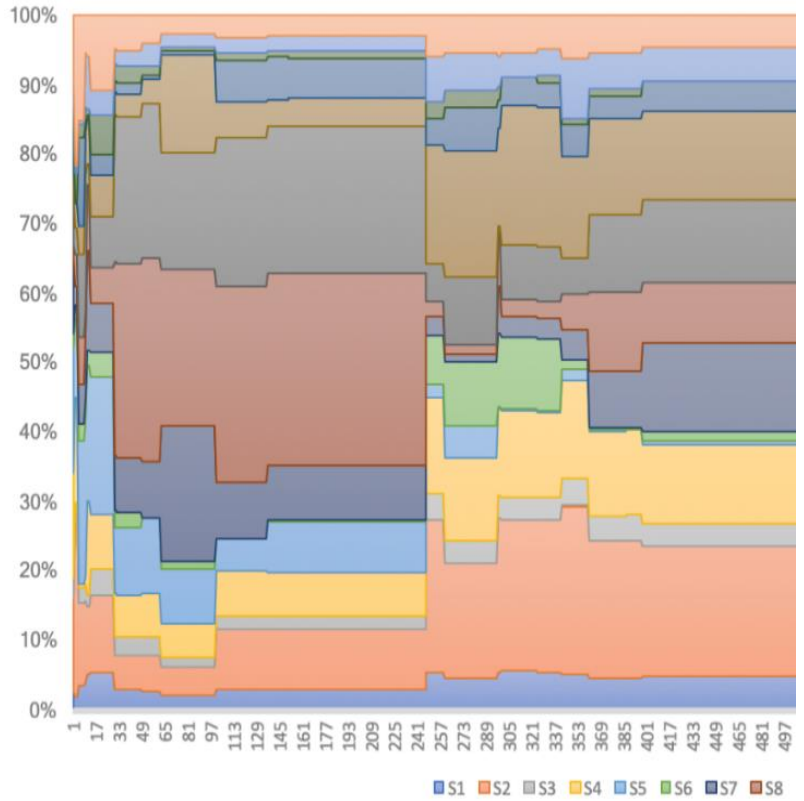
Genetic Programming for Big Data Analytics (Current)



Advancing Genetic Programming via Information Theory



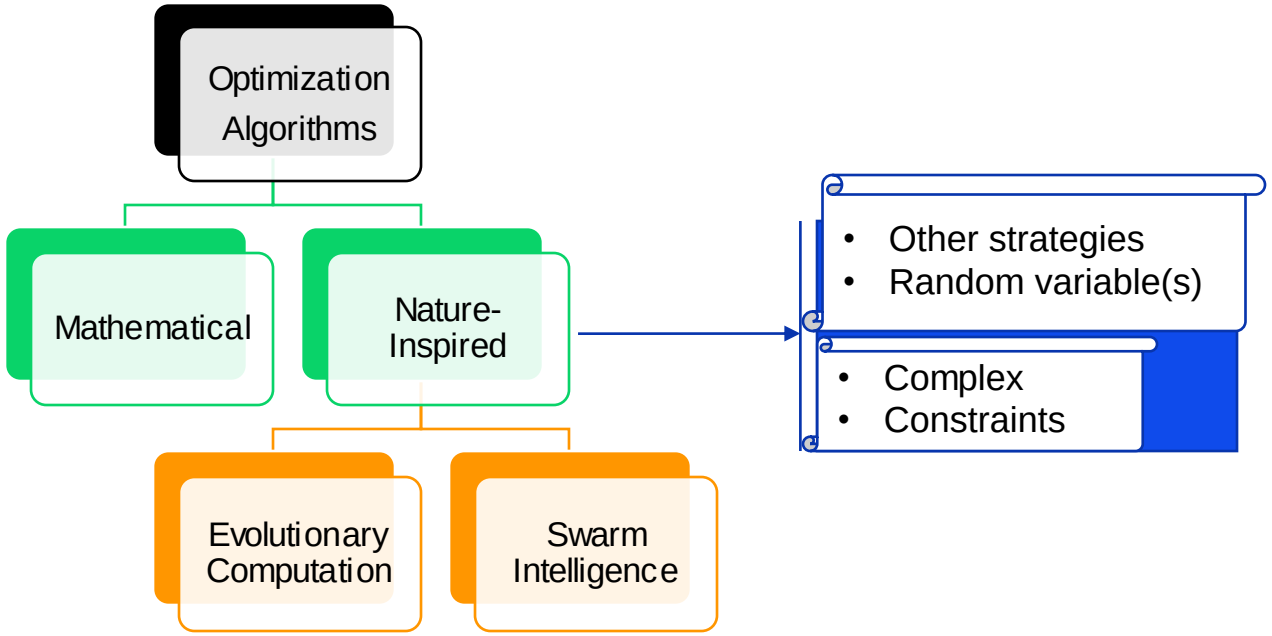
Population size	Method	WIR	WIW
1,000	MR	0.1012	0.0992
	GP	0.1084	0.1048
	RRGP	0.1012	0.1094
	MRGP-TC	0.1172	0.0958
	MRGP-SumT	0.1115	0.0959
	MRGP-MDL	0.1120	0.0960
	MRGP-SMDL	0.1347	0.0961
100	MRGP-TC	0.1085	0.0961
	MRGP-SumT	0.1076	0.0963
	MRGP-MDL	0.1030	0.0964
	MRGP-SMDL	0.1080	0.0968
	Proposed GP	**0.0617**	**0.0664**



Grin, A.V. and Gandomi, A.H., 2021, June. Advancing Genetic Programming via Information Theory. In 2021 IEEE Congress on Evolutionary Computation (CEC) (pp. 1991-1998). IEEE.

EC for Optimization

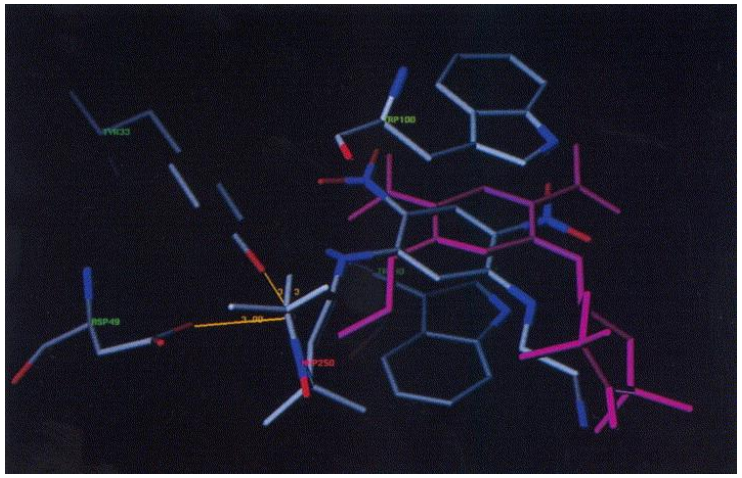
Optimization Algorithms



EC in Real-World Problems

Boeing Turbine geometry of 777 GE engine Design:

Charles W. Petit, “Touched by nature: putting evolution to work on the assembly line.” US News & World Report, volume 125, issue 4, pages 43–45 (1998).



Merck Pharmaceutical discovered first clinically-approved antiviral drug for HIV:

Jones G, Willett P, Glen RC, Leach AR, Taylor R (1997) Development and validation of a genetic algorithm for flexible docking. J Mol Biol 267: 727–748.

& so many other companies.

amazon

Google Brain

Uber

BMW

Oral-B

Traditional Algorithms:

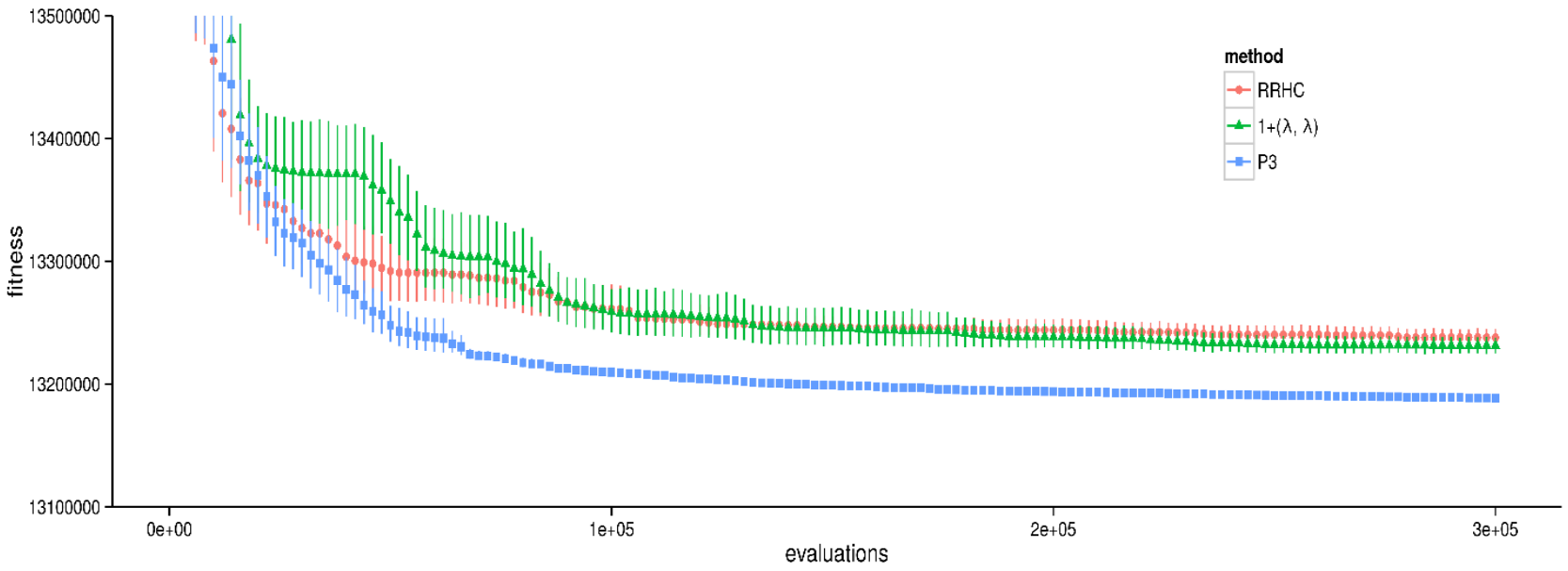
Genetic Algorithm (GA)
Simulated Annealing (SA)
Particle Swarm Optimization (PSO)

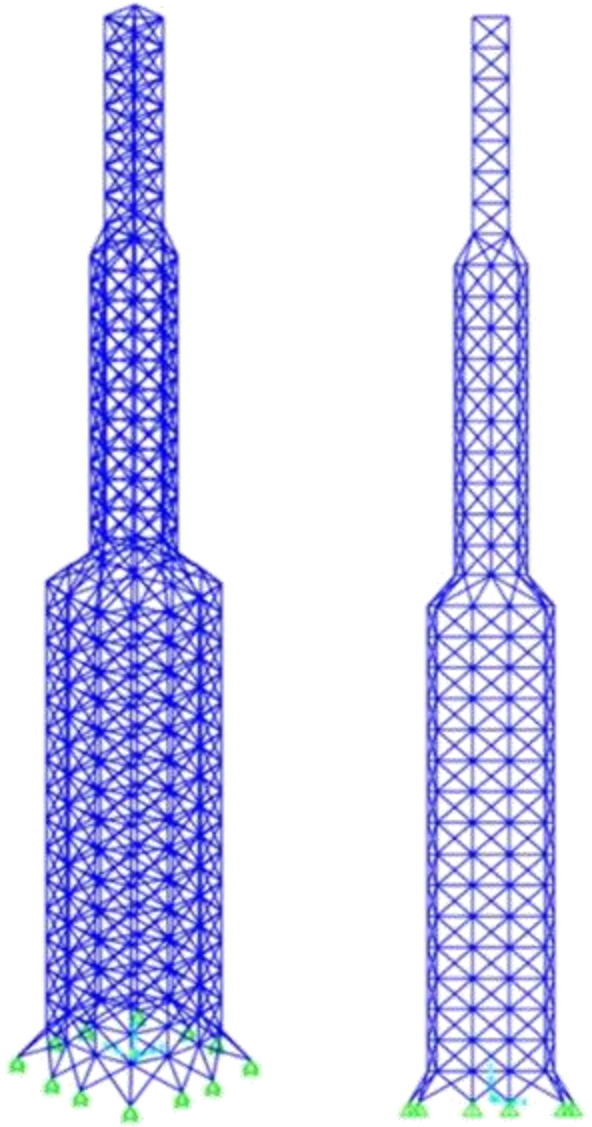
Recent Algorithms:

Hunger Games Search (HGS)
Reptile Search Algorithm (RSA)
Colony Predation Algorithm (CPA)
Runge Kutta based Algorithm (RUN)
Material Generation Algorithm (MGA)
Arithmetic Optimization Algorithm (AOA)
Quantum-based Avian Navigation Algorithm (QANA)
Aquila Optimizer (AO)
Krill Herd Algorithm (KH)
Fire Hawk Optimizer (FHO)
Salp Swarm Algorithm (SSA)
Interior Search Algorithm (ISA)
Prairie Dog Optimization (PDO)
Marine Predators Algorithm (MPA)

Complex Systems: 35-Storey Space Tower

1262 members and 936 degrees of freedom





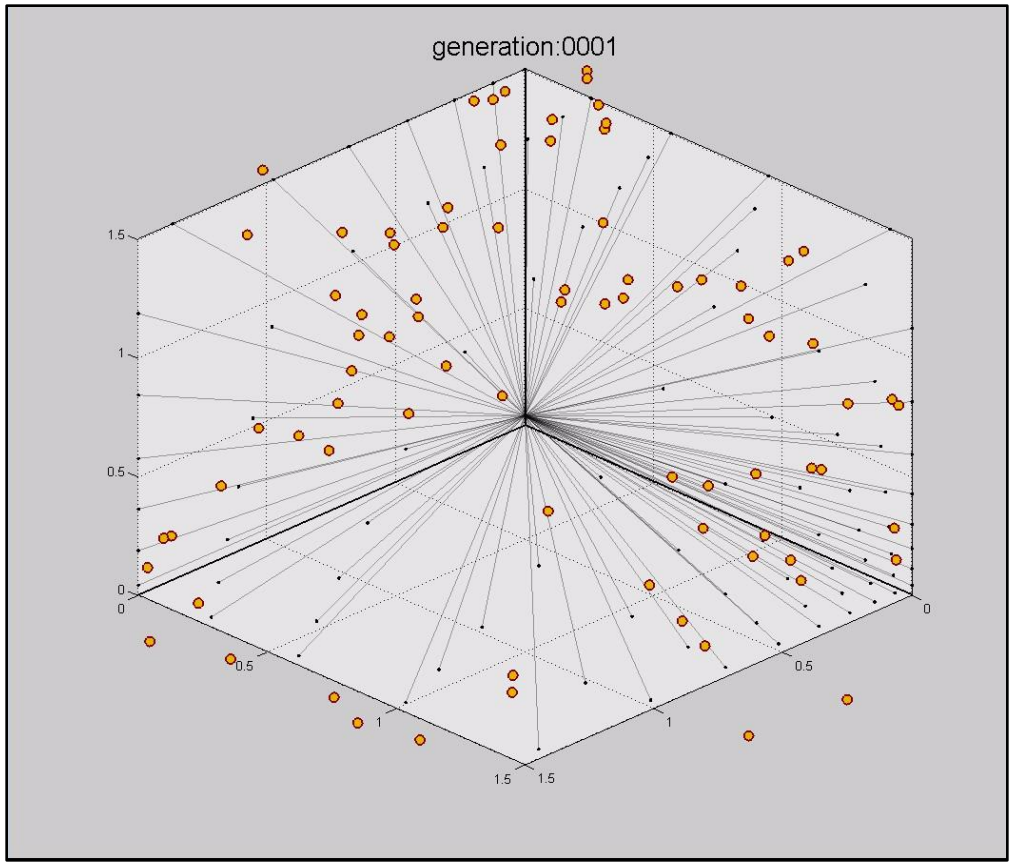
Gandomi, A. H., & Goldman, B. W. Parameter-less population pyramid for large-scale tower optimization. Expert Systems with Applications, 96, 175-184, 2018.

Many Objective Evolutionary Optimization

- 18 evolutionary many-objective algorithms are compared against well-known combinatorial problems!

- knapsack problem,
- traveling salesman problem,
- quadratic assignment problem

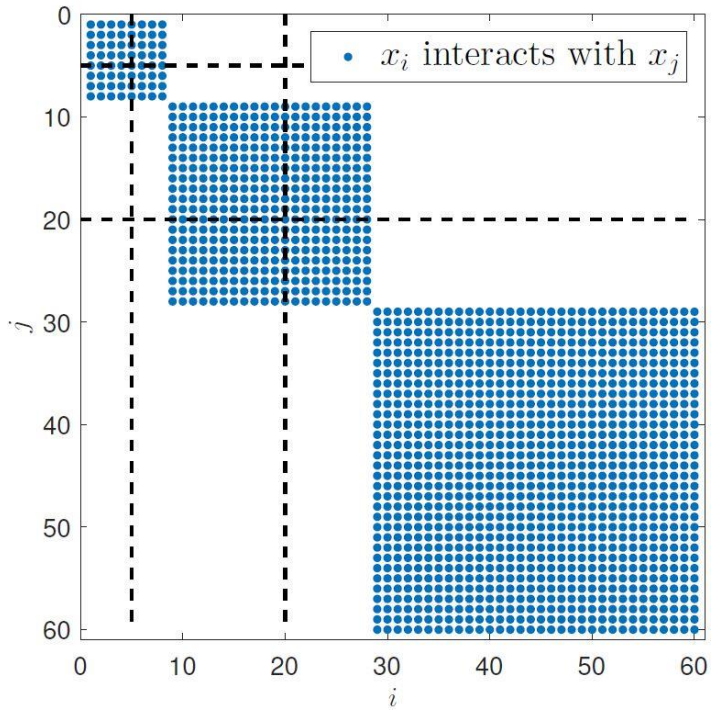
- 3, 5, and 10 objectives problems are tested



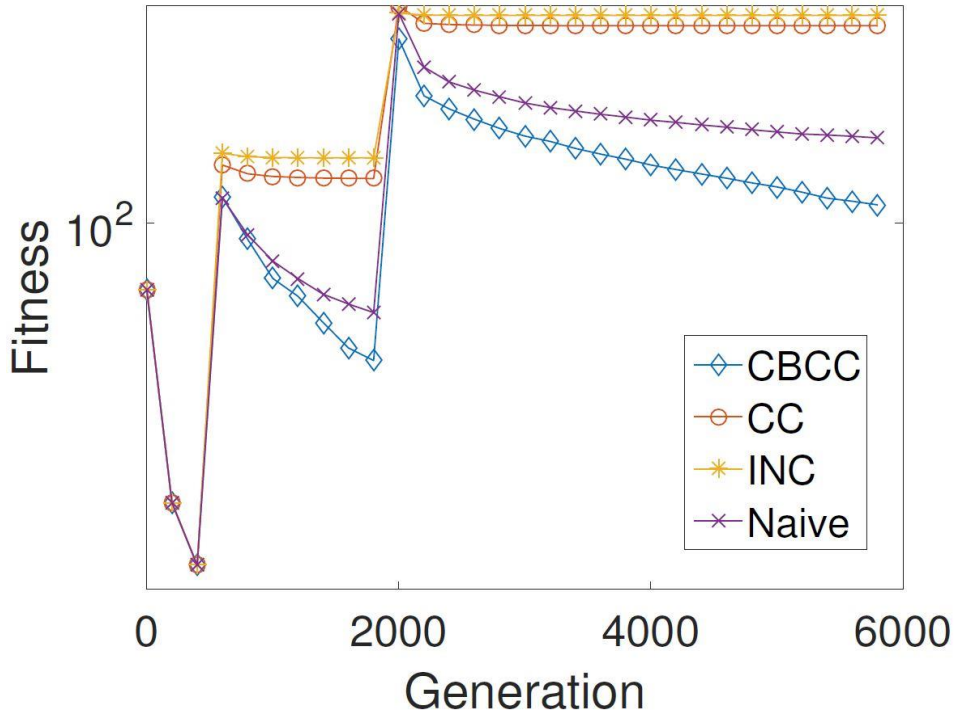
Behmanesh, R., Rahimi, I., & Gandomi, A. H. (2020). Evolutionary Many-Objective Algorithms for Combinatorial Optimization Problems: A Comparative Study. Archives of Computational Methods in Engineering, 1-16.

Incremental Optimization Problems

Increments:
from 5 → 20 → 60 variables



CBCC (proposed)



Cheng, Omidvar, Gandomi, et al. 2019 Solving Incremental Optimization Problems via Cooperative Coevolution. IEEE Transactions on Evolutionary Computation, 23(5), 762 – 775.

Domain Knowledge

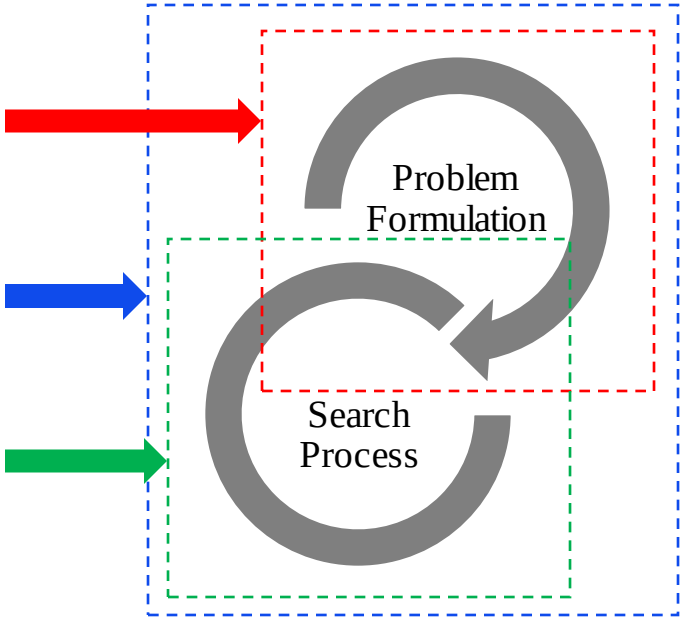
Possible Knowledge

Expert Knowledge

Information and Mathematical Theories

Engineering Principles

Scientific Concepts



Tutorial (most recent):

Gandomi, A.H., (2022) ACM GECCO 2022# embedding knowledge into optimization process. In *Proceedings of the Genetic and Evolutionary Computation Conference Companion, ACM* (pp. 922-936). DOI 10.1145/3520304.3533641

Embedding Knowledge

Variable Functioning
Semi-Independent Variables
Boundary Updating

UTS

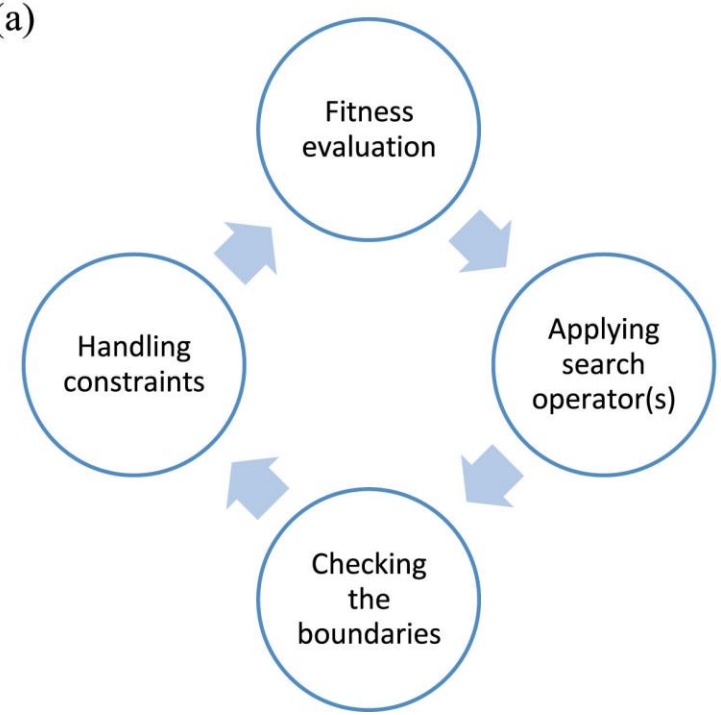
Semi-Independent Variables (SIV)

Gandomi, A.H., Deb, K., Averill, R.C., Rahnamayan, S. and Omidvar, M.N., 2018. Using Semi-independent Variables to Enhance Optimization Search. *Expert Systems with Applications*. 120, 279-297, 2019.

Boundary Updating

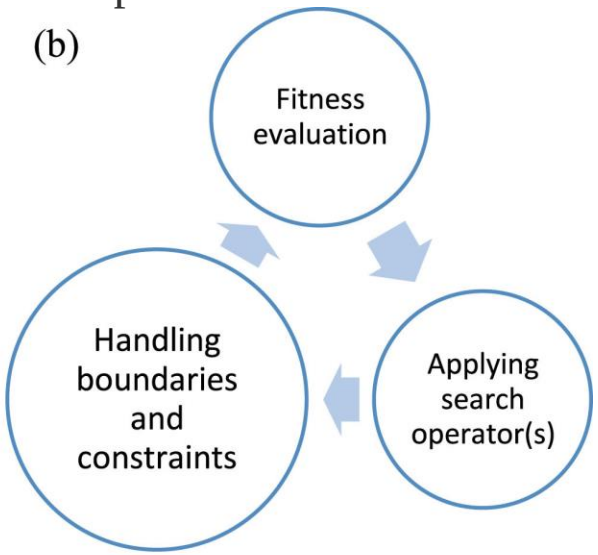
Common

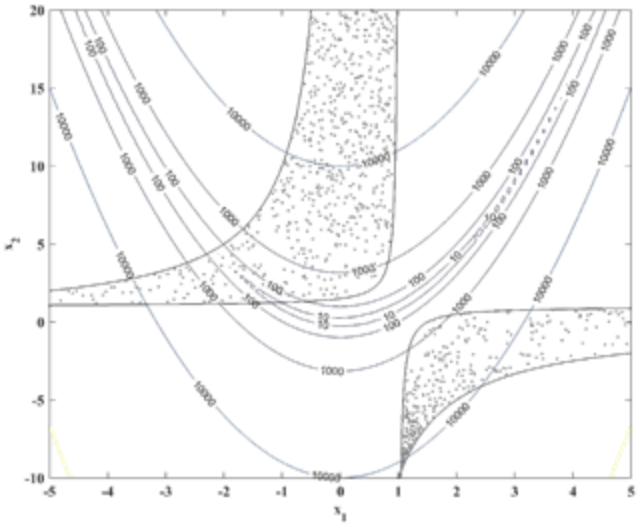
(a)

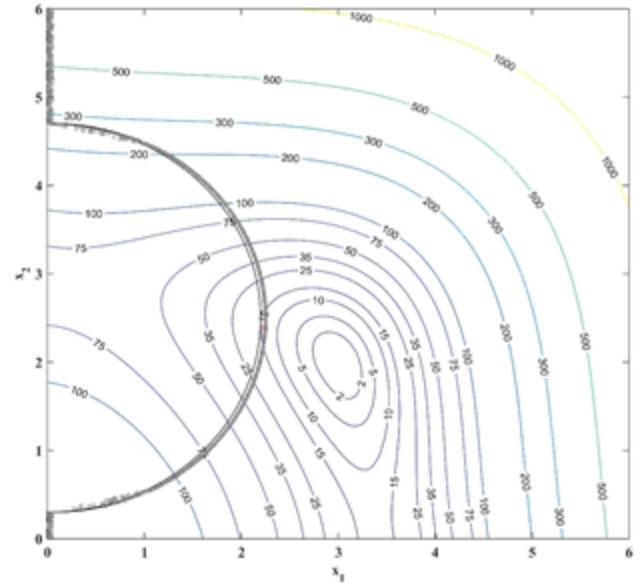


Proposed

(b)



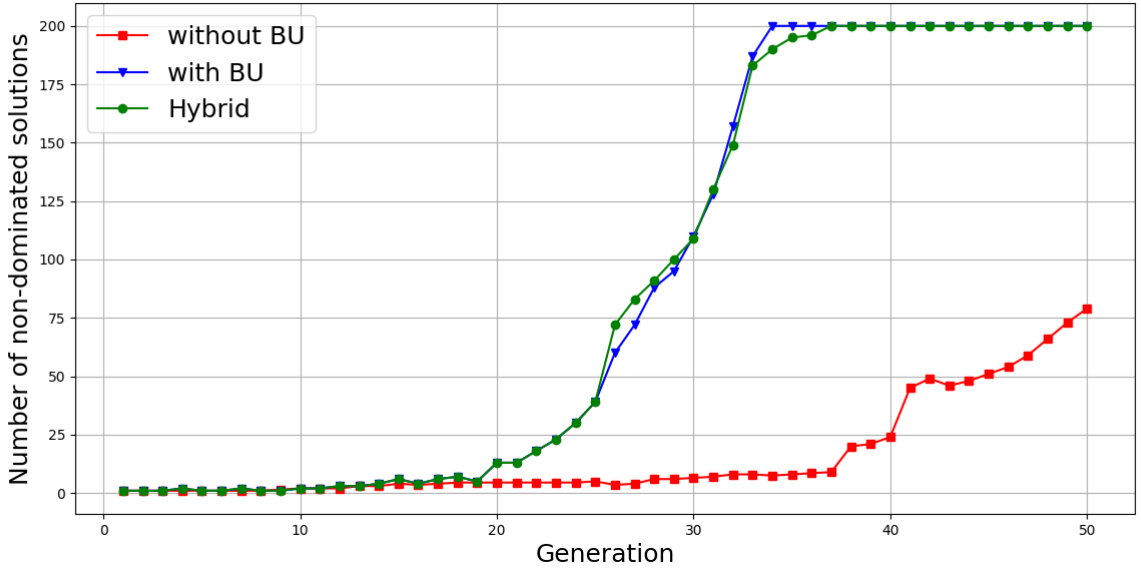




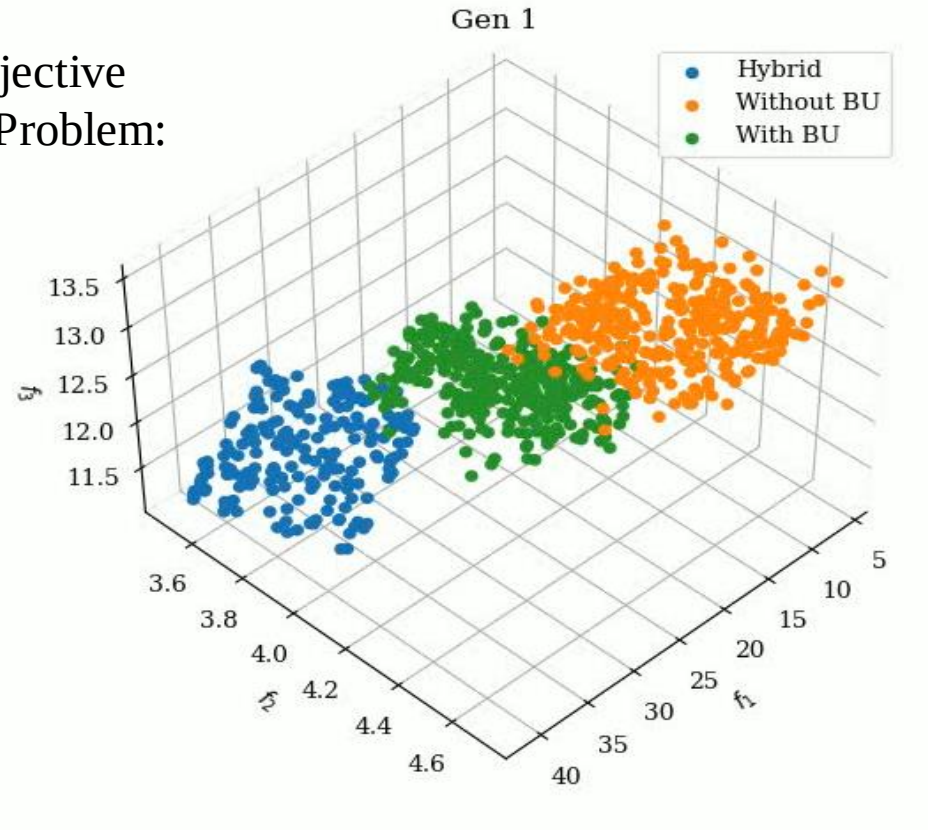
Gandomi, A. H., & Deb, K. (2020). Implicit constraints handling for efficient search of feasible solutions. *Computer Methods in Applied Mechanics and Engineering*, *363*, 112917.

Boundary Updating in Multi/Many Objective Optimization

Bi-Objective Problem:



Many-Objective
Car Side Problem:



Rahimi, I., Gandomi, A.H. et al. Augmented boundary updated constraint handling technique.

EI for Combating COVID-19

XPRIZE-Cognizant Pandemic Challenge

F1: daily new cases
F2: stringency of planned interventions

UTS team:
I led team **Kangaroos** in this competition
Our team used

- ML to build models
- EMO to optimize the objectives

Results:

- We were the only team from Australia to reach the final
- We end up as a top-ten team
- We became one of the Honourable Mention Winners

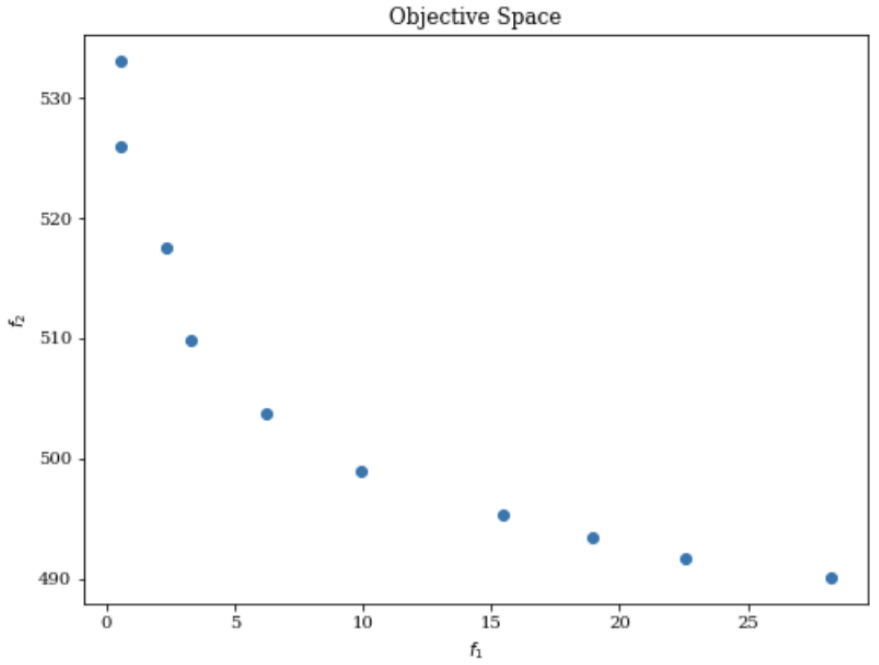


Figure 1. Sample Pareto Front for Canada

https://www.bloomberg.com/press-releases/2021-03-09/xprize-and-cognizant-announce-grand-prize-winners-in-pandemic-response-challenge-to-restart-economies-around-the-world

Aims and Objectives

Promoting through AI research

- Stablishing a world-class research group in AI
  - Solving industry and humanity problems in Hungary and all over the world
- Building a big network of collaborators
  - Colleagues at Óbuda University
  - Researchers from other research centres all over the world
- Making connections with AI leading centres
  - Signing MoU
  - Joint Research Centre
  - Developing Joint PhD Program
- Rising the research profiles
  - Increasing high quality publications in prestigious journals
  - Representation in world-leading venues (journals and conferences)

Collaborative Works

- ✓ Data Analytics
- ✓ Optimization

ÓBUDAI EGYETEM
ÓBUDA UNIVERSITY

Thank you!

Amir H Gandomi

Professor of Data Science at University of Technology Sydney
(newly) Distinguished Professor at Óbuda University