Research progress report

M1 - Master Program in Computer Science

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Agenda

Optimization

What is optimization?

- An optimization problem, in a basic form, consists of solving the task of maximizing or minimizing a real function.

Figure 1: Local and Global optimums [2]

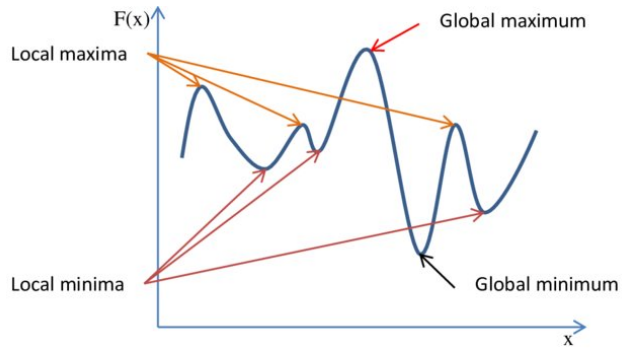
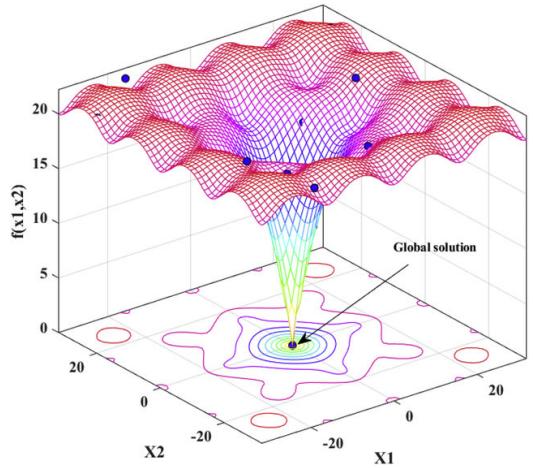
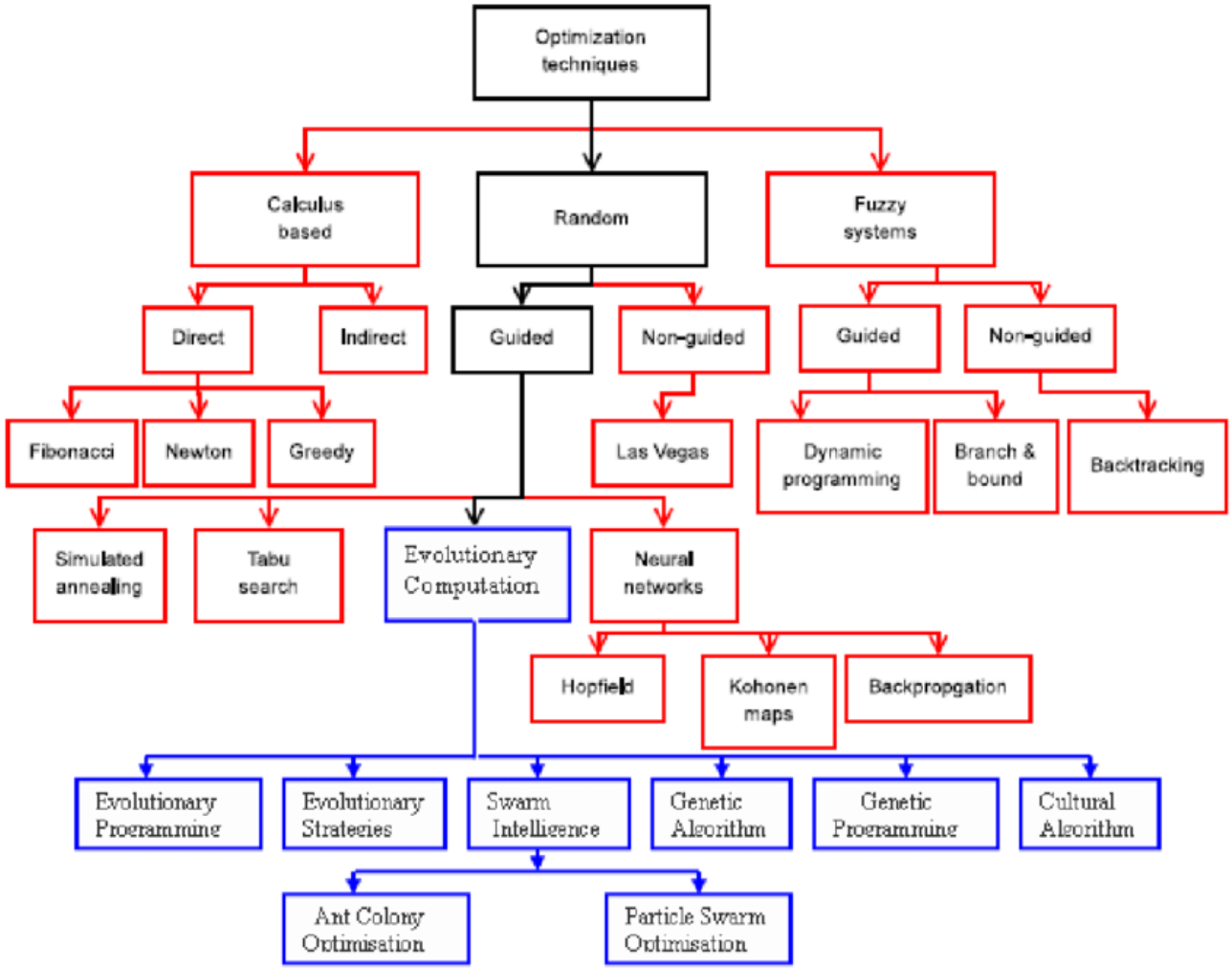


Figure 2: 3D Single objective problem [6]



Evolutionary algorithms (EA)

Figure 3: Diagram of optimization techniques [3]

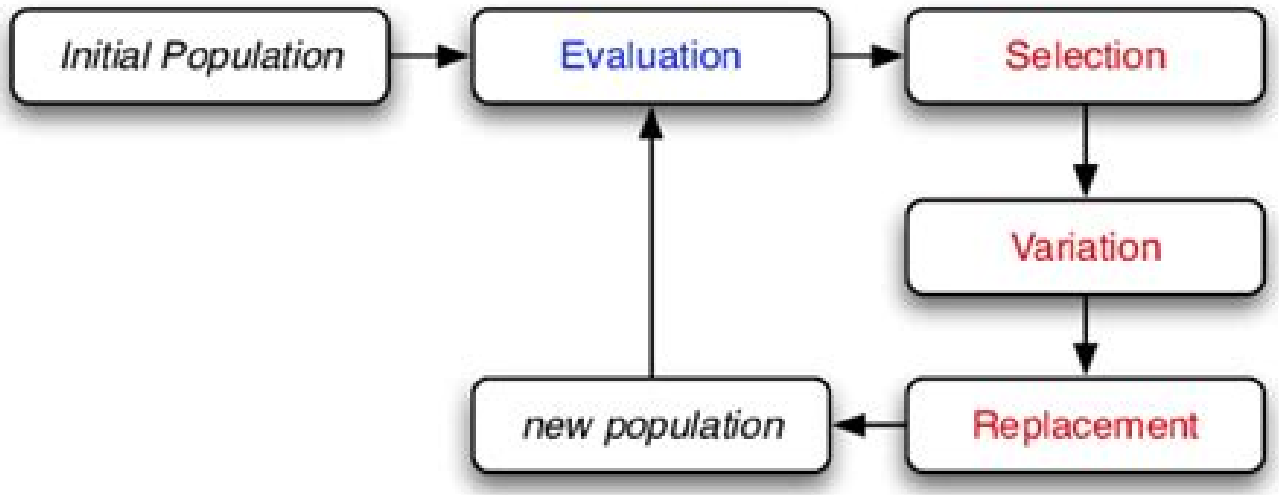


Evolutionary algorithms (EA)

What is Evolutionary Algorithms?

- Evolutionary approaches usually follow a specific strategy with different variations to select candidate elements from population set and evolve then to improve the quality of modified elements;
- These algorithms can be applied to several problems of optimization and be performed in any programming language.

Figure 4: Simplified version of the process of an EA [5]

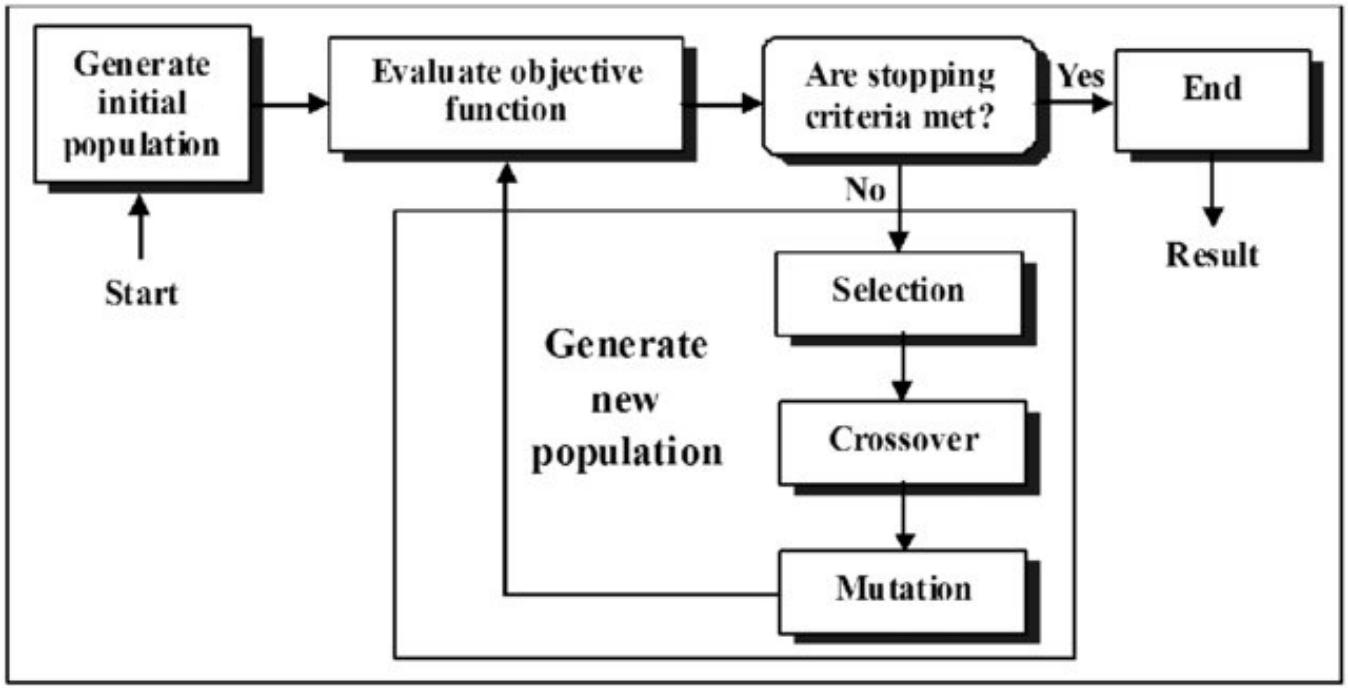


Evolutionary algorithms (EA)

Genetic Algorithm (GA)

- A widely used evolutionary algorithm inspired by Darwin's natural evolution. In order to obtain an optimal solution to the problem, it uses biological operators such as mutation, elitism, crossover and selection.

Figure 5: Block diagram of basic GA operation [1]



Evolutionary algorithms (EA)

Mutation

Before Mut $->$ [1] [0] [1] **[1]** [0] [0] [0] [0] (1)

(2)

After Mut $->$ [1] [0] [1] **[0]** [0] [0] [0] [0] (3)

Crossover

Parent 1 $->$ [1] [0] [1] [1] | [1] [1] [1] [0] (4)

Parent 2 $->$ [0] [0] [0] [0] | [0] [0] [0] [0] (5)

(6)

Child $->$ **[1] [0] [1] [1] | [0] [0] [0] [0]** (7)

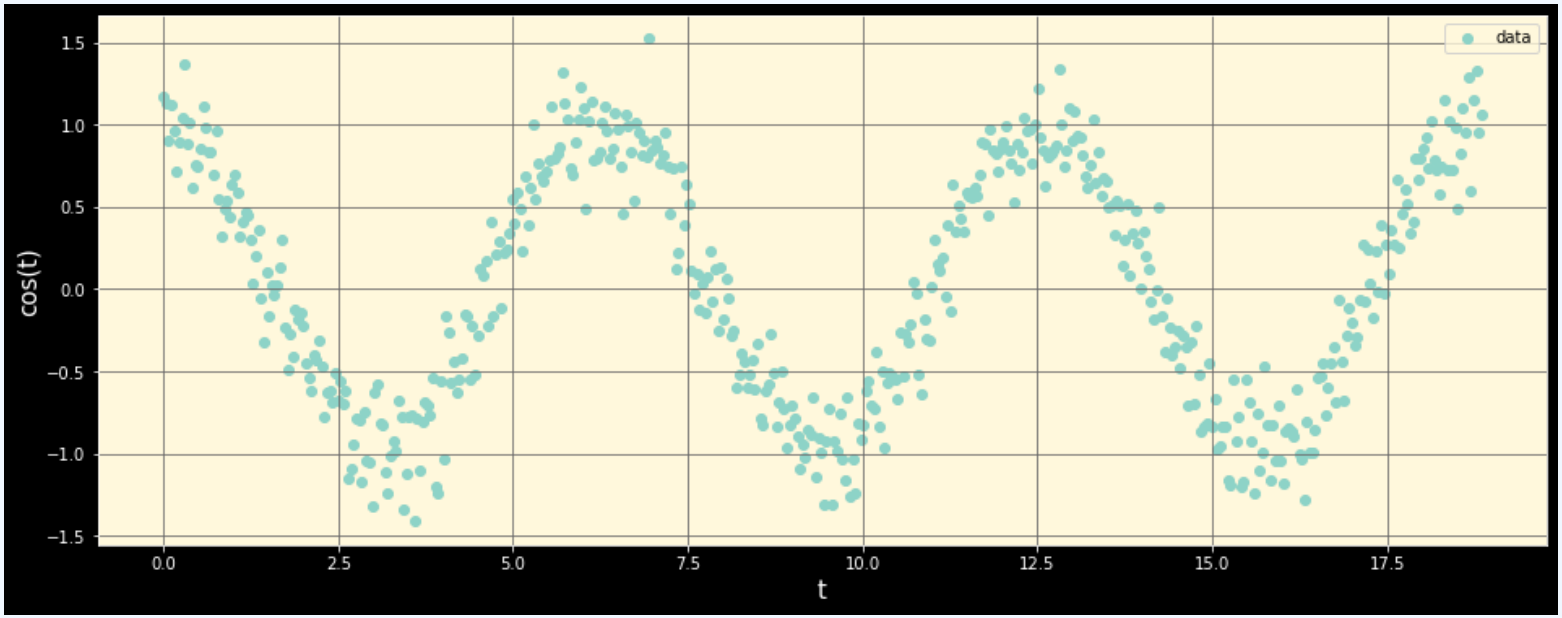
Single objective problem (SOP) and Multi-Objective Problem (MOP)

Single objective problem

- Single objective problems are those where it is necessary to worry about minimizing (or maximizing) only a single parameter.

Find coefficients

Given the noisy cosine $f(t) = cos(t) + noise$, find the values of the first seven coefficients for a Fourier Series that fits it with error less than 0.25.



Single objective problem (SOP) and Multi-Objective Problem (MOP)

Find coefficients in Fourier series

$$F(x) = \frac{a_0}{2} + \sum_{n=1}^{x} \left[a_n cos(nx) + b_n sin(nx) \right] \quad (8)$$

$$cos(t) + noise \approx \frac{a_0}{2} + a_1 cos(t) + b_1 sin(t) + ... + a_3 cos(3t) + b_3 sin(3t) \quad (9)$$

$$f(t) \approx model(t) \longrightarrow diff = model(t) - f(t) \quad (10)$$

$$Error = \sqrt{\frac{diff^2}{n}} \quad (11)$$

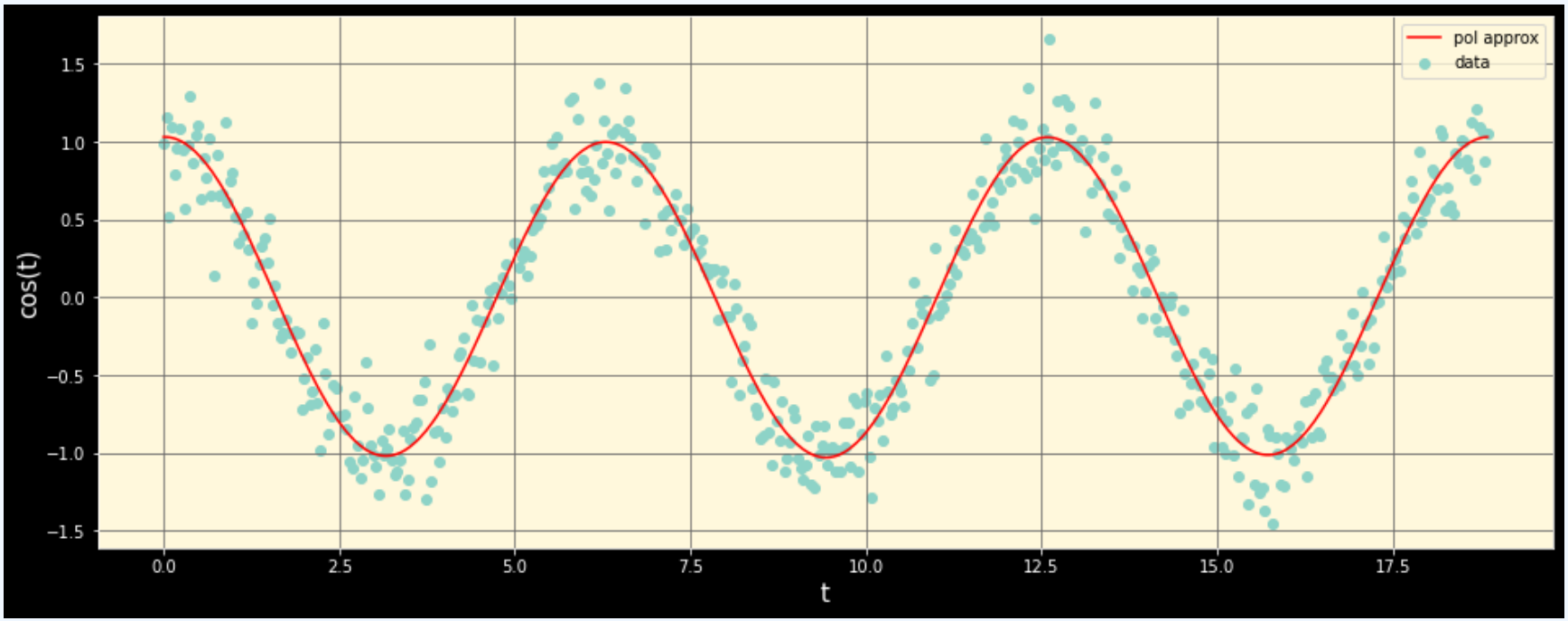
And now the problem is to minimize the error:

$$Error \leq 0.25 \quad (12)$$

Single objective problem (SOP) and Multi-Objective Problem (MOP)

Find coefficients in Fourier series

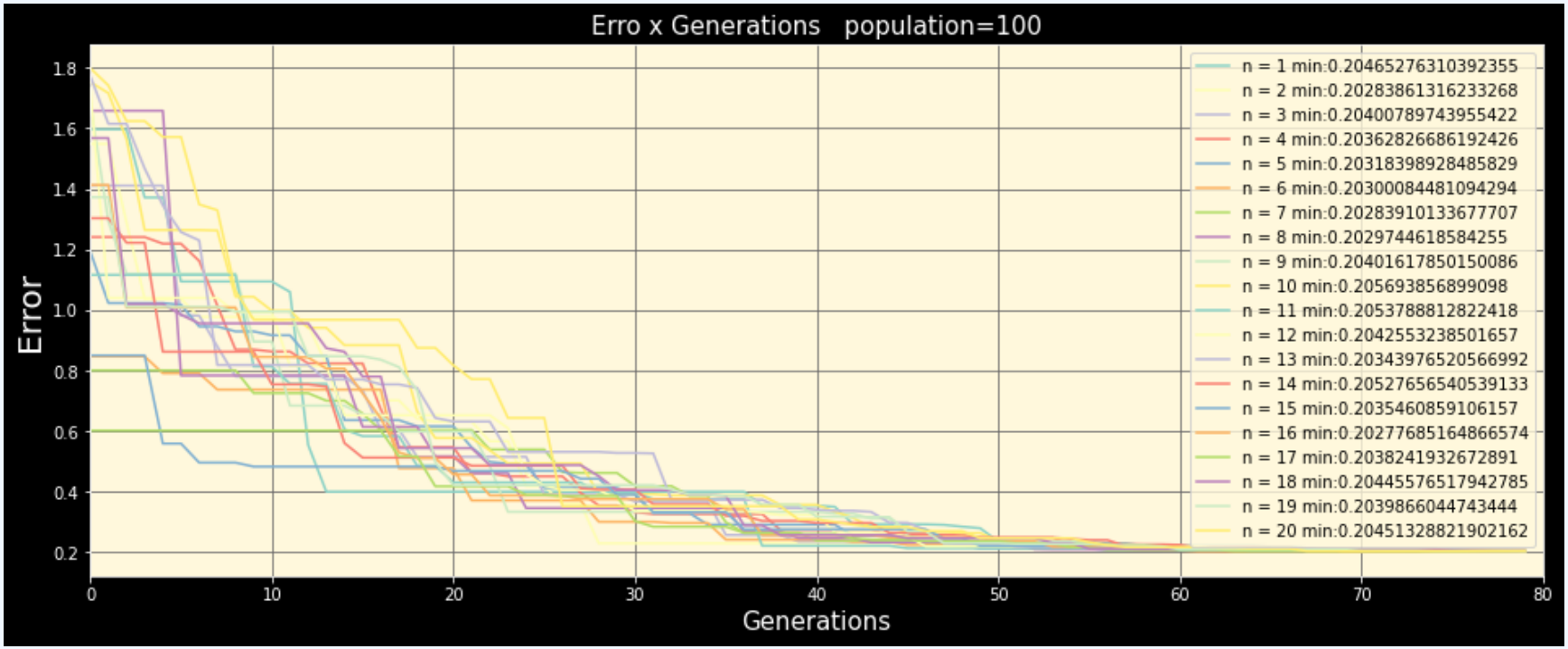
Figure 6: Cosine approximated by Fourier series



Single objective problem (SOP) and Multi-Objective Problem (MOP)

Find coefficients in Fourier series

Figure 7: Evolution of the error over the generations



Single objective problem (SOP) and Multi-Objective Problem (MOP)

Multiple objective problem

- Multi-objective problems are those where there is more than one objective to be taken into account.

Knapsack problem

This problem consists in filling a backpack with items from the n available. However, each item has a weight (w) and a value (p), and the conditions of the problem are: Maximize the sum of the value of all items subject to a maximum weight that can be in the bag (W) as a sum of the weight of all items in it.

$$maximize \sum_{i=1}^{n} x_i p_i \tag{13}$$

$$subject\ to \sum_{i=1}^{n} x_i w_i \leq W \tag{14}$$

$$x_i \in \{0, 1\},\ i = 1, 2, 3, ..., n$$

Single objective problem (SOP) and Multi-Objective Problem (MOP)

Some methods for multi-objective problems

Several methods and algorithms have been proposed to solve multi-objective optimization problems. Just as an example, it is worth mentioning one of them:

- **Based on Decomposition:**
  It decomposes a multiobjective optimization problem into a number of scalar optimization subproblems and optimizes them simultaneously [7];

State Of The Art

SOTA

Today several researches are being done in order to improve the way in which the evolutionary algorithms solve problems (Execution time, number of evaluations, complexity, precision and so on), whether single or multi-objective. Recent publications are things like:

- Improve the way you set value to algorithm parameters. Making this decision dynamic and no longer static and using online models to modify the values;
- New strategies to get out of local optimums;
- Improve the visualization of the results found and the progress of the EAs;
- New approaches to the evolution of EAs based on different areas of knowledge.

Goals

New approaches in EA

To study and propose new approaches in EA, mainly based on theories of physics. One example is [4] that uses the Theory of General Relativity to introduce a new evolutionary optimization algorithm.

Applications in the industry

Apply the different algorithms and approaches in industrial maintenance problems, both in failure prediction and control systems. Preferably on public rail transport systems.

[1] Sabah Abdulazeez and Hebah H. O. Nasereddin. “Enhanced Solutions for Misuse Network Intrusion Detection System using SGA and SSGA”. PhD thesis. June 2015. DOI: 10.13140/RG.2.1.2431.9125.

[2] Victor Alves Ribeiro. “Soft Computing Techniques for UAVs Classifiers using Micro-Doppler Signatures”. In: (Apr. 2016).

[3] Guy Baele et al. “Open-ended On-board Evolutionary Robotics for Robot Swarms”. In: May 2009, pp. 1123–1130. DOI: 10.1109/CEC.2009.4983072.

[4] Hamzeh Beiranvand, Esmaeel Rokrok, and Karim Beiranvand. “General Relativity Search Algorithm for Optimization in Real Numbers Space”. In: **International Journal of Mechatronics, Electrical and Computer Technology (IJMEC)** 5 (Apr. 2015), pp. 2157–2168.

[5] Elhadj Benkhelifa et al. “Design and optimisation of microelectromechanical systems: A review of the state-of-the-art”. In: **International Journal of Design Engineering** 3 (Jan. 2010). DOI: 10.1504/IJDE.2010.032822.

[6] Hussein Ridha et al. “Multi-objective optimization and multi-criteria decision-making methods for optimal design of standalone photovoltaic system: A comprehensive review (Renewable and Sustainable Energy Reviews, Impact Factor: 16.799)”. In: **Renewable and Sustainable Energy Reviews** 135 (Jan. 2021), p. 110202. DOI: 10.1016/j.rser.2020.110202.

[7] Qingfu Zhang and Hui Li. “MOEA/D: A Multiobjective Evolutionary Algorithm Based on Decomposition”. In: **Evolutionary Computation, IEEE Transactions on** 11 (Jan. 2008), pp. 712–731. DOI: 10.1109/TEVC.2007.892759.

That's all, folks!

Thank you!