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SOLUTION OF A PURCHASING SCHEDULING PROBLEM WITH CONSTRAINED FUNDS THROUGH A GENETIC ALGORITHM BASED ON THE PARETIAN APPROACH

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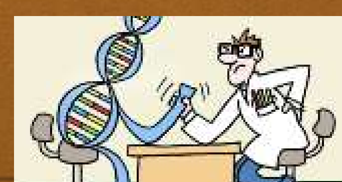

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- The Paretian Approach
- The Purchasing Scheduling problem
- The Genetic Algorithm
- Experiments and results
- Conclusions
- Future Works

The Paretian approach

- The 80/20 rule: For many events, roughly 80% of the effect comes from 20% of the causes (machines, raw materials, operators, etc.).

- Multiobjective optimization.
  - Involve more than one objective function
  - Answer is set of solutions that define the best tradeoff between competing objectives.

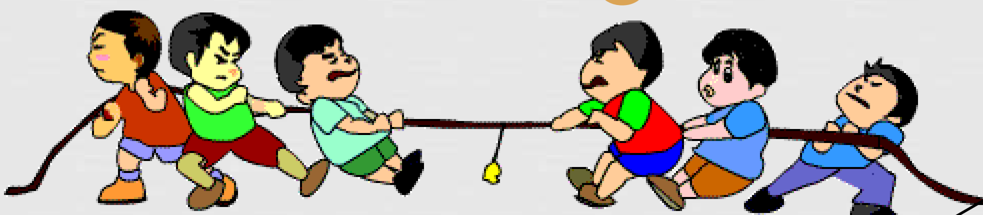
The Paretian approach

- Application example:

  Quality control of a product

The Paretian Approach

Dominant (winner)



Objetive 1 Objetive 2

A value function (a cell)

Decision	Objetive 1	Objetive 2	Objetive 3	…	Objetive n
Objetive 1	Winner (optimal)	Loser	Loser		Loser
Objetive 2	Loser	Winner (optimal)	Loser		Loser
Objetive 3	Loser	Loser	Winner (optimal)	…	Loser
…	…	…	…	…	…
Objetive n	…	…	…	…	Winner (optimal)

The Purchasing Scheduling Problem (PSP)

Scenario: orders placed by assistants or a manager in a purchasing department given a general product catalogue.

An order k

Purchasing Costs c_{ij}

Demand Satisfaction

Product i / Supplier j		HP	Dell	Office Depot	Office Max	…	Required units
1	Computer	\$1,000	\$2,000	\$0	\$0	…	2
2	Printer	\$500	\$700	\$0	\$0	…	1
3	Scanner	\$1,000	\$2,000	\$0	\$0	…	5
4	Desk	\$0	\$0	\$1,500	\$1,000	…	11
5	Chair	\$0	\$0	\$3,000	\$2,500	…	7
…	…	…	…	…	…	…	…
10000	…	…	…	…	…	…	…

Available resources

Products per order: n_k

Available funds (a_k): \$50,000

The Purchasing Scheduling Problem (PSP)

Mathematical formulation

$$\max z = \sum_{i=1}^{n} \frac{f_i}{n}$$

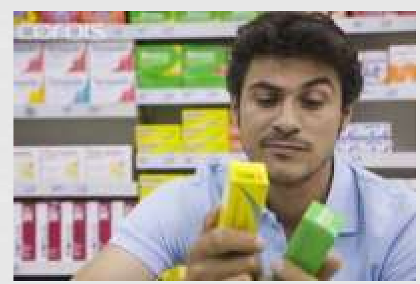
Uniform distribution of objectives

Sujeto a:

$$\sum_{j=1}^{m} \sum_{i=1}^{n_k} c_{ij} x_{ijk} \le a_k \qquad k = 1,2,\ldots,s$$

Available funds

$$x_{ijk} \in \{0,1\}$$

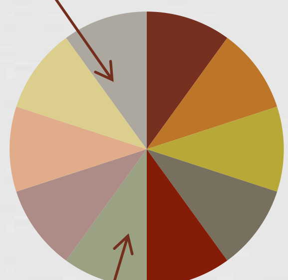


The Purchasing Scheduling Problem (PSP)

Demands

$$\max f_1 = \frac{1}{\sum_{k=1}^{s} n_k} \sum_{k=1}^{s} \sum_{j=1}^{m} \sum_{i=1}^{n_k} x_{ijk} \qquad 0 \le f_1 \le 1$$

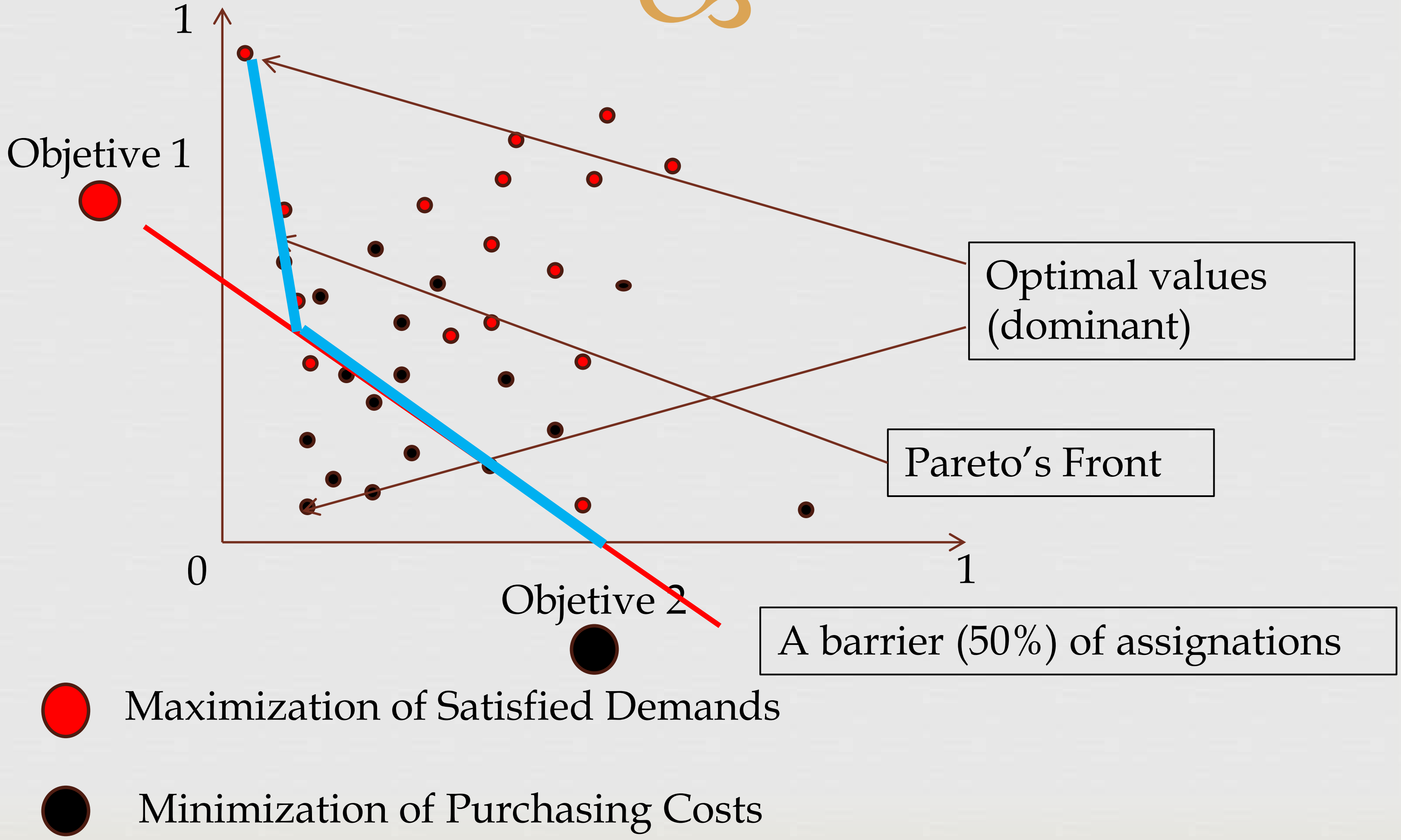
Uniform assignation



Purchasing Costs

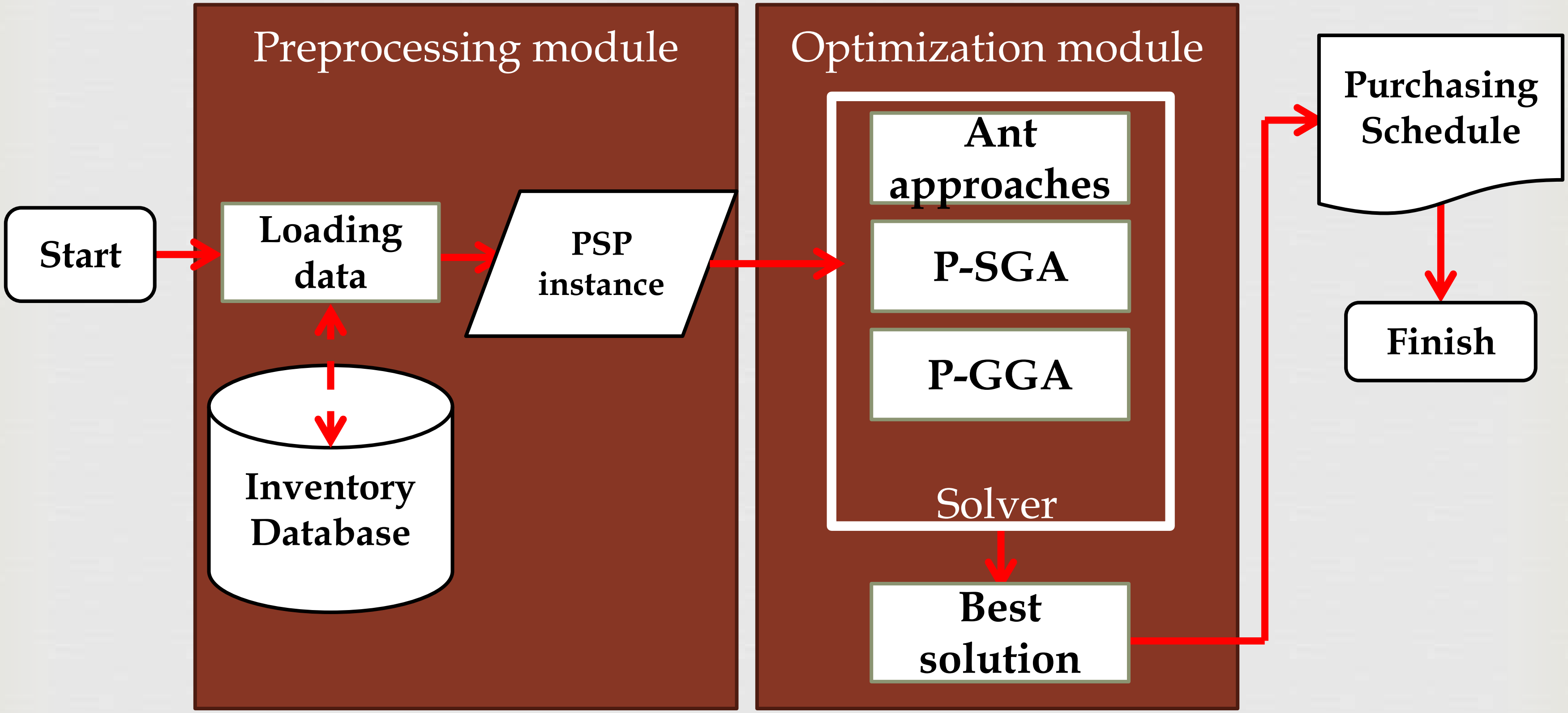
$$\min f_2 = 1 - \frac{\sum_{k=1}^{s} \sum_{j=1}^{m} \sum_{i=1}^{n_k} c_{ij} x_{ijk}}{\sum_{j=1}^{m} \sum_{i=1}^{n} c_{ij}} \qquad 0 \le f_2 \le 1$$

The Purchasing Scheduling Problem (PSP)



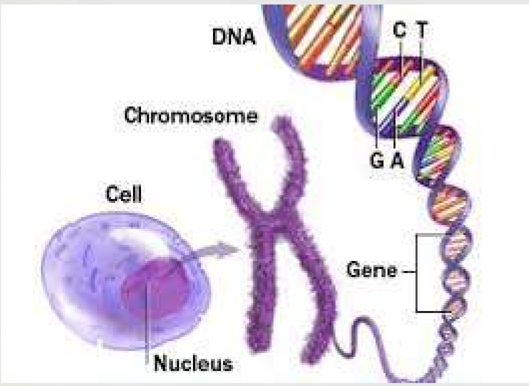
Methodology of solution

Architecture of solution



The Genetic algorithm

John Holland (1975)



Natural Selection
Charles Darwin (1858)

*Pop = population of individuals

```
Procedure  GeneticAlgorithm( )
   t = 0
   initialize(Pop(t))
   evaluate(Pop(t))
   While (stop condition is not reached)
          selection (Pop(t + 1), Pop(t))
          crossover (Pop(t + 1))
          mutation (Pop(t + 1))
          t = t + 1
   End_of_while
End_Procedure
```

Natural Selection: process in which an organism adapts to its environment by means of selectively reproducing changes in its genotype.

Selection operator: the fittest individuals of the population are selected to reproduce them.

The Genetic Algorithm

Coded schemes (strings of chromosomes)

O_1:

s_1	s_2	s_3	s_1	s_2	s_3	s_1	s_2	s_3
1	0	1	0	1	1	1	1	1
	p_1			p_2			p_3	

O_2:

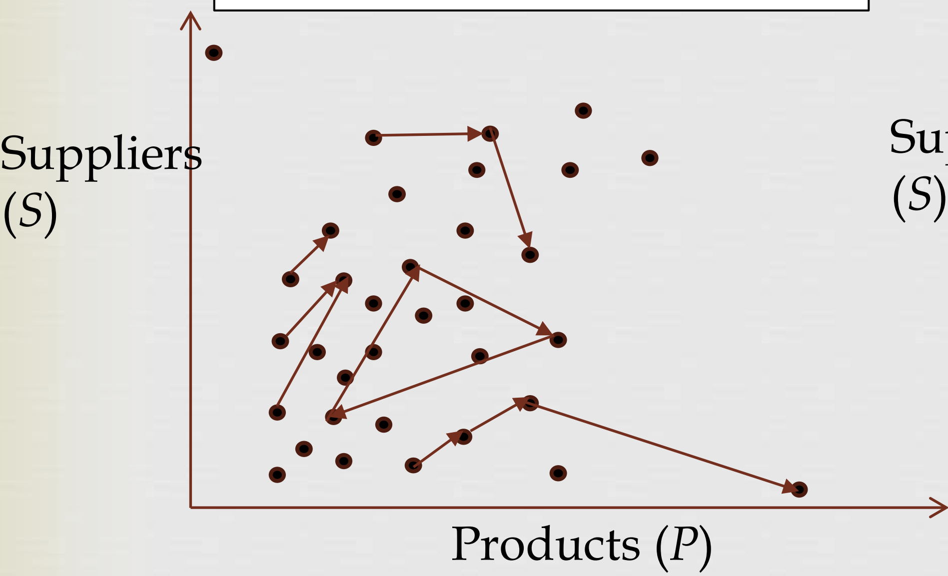
s_1	s_2	s_3	s_1	s_2	s_3	s_1	s_2	s_3
0	0	1	1	0	1	1	0	1
	p_1			p_2			p_3	

O_1:

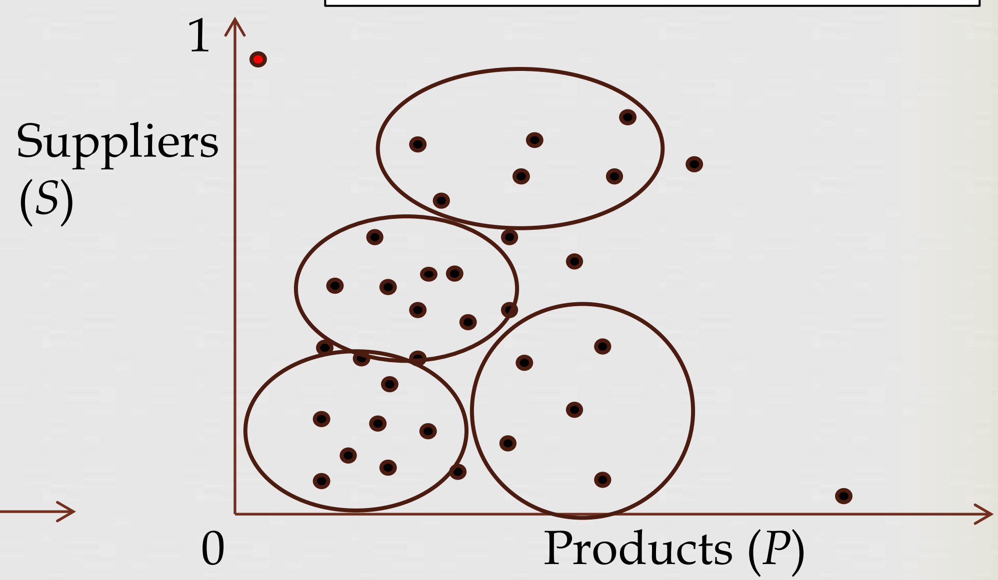
1, 5, 2	3, 6, 9	4, 7, 8
p_1	p_2	p_3

O_2:

2, 4, 6	1, 3	5, 7, 8
p_1	p_2	p_3



Simple Genetic Algorithm



Grouping Genetic Algorithm

The Genetic algorithm

- The crossover operators
- One point

Parents

0	1	0	0	0	0	0	1	1
0	1	0	0	0	0	0	1	1

1	0	0	0	1	0	0	1	1
1	0	0	0	1	0	0	1	1

Descendants

- Two points

Parents

0	1	0	0	0	0	0	1	1
0	1	0	0	0	0	0	1	1

1	0	0	0	1	0	0	1	1
1	0	0	0	1	0	0	1	1

Descendants

Constructive parameter: a crossover rate (p_c)

The Genetic Algorithm

- Crossover operators (Grouping schemes)

A	B	C	D	E	F
A	B	C	D	E	F

C	F	D	A	E	B
C	F	D	A	E	B

Elements of groups D and F are reallocated

INFEASIBLE

Repair techniques :

First Fit Decreasing (FFD) -Best Fit Decreasing (BFD)

Falkenauer E., 1996. A Hybrid Grouping Genetic Algorithm for Bin Packing. Journal of Heuristics 2: 5-30.

The Genetic Algorithm

- Mutation Operator

P-SGA

0	1	0	0	0	0	0	1	1

1	1	0	0	1	0	0	1	1

P-GGA

D	E	F	A	C	B

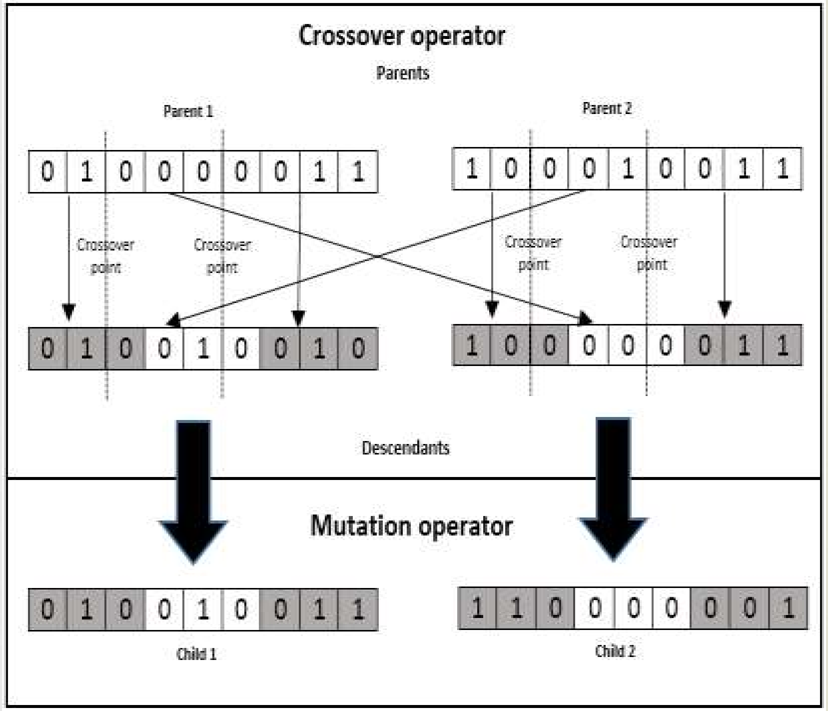
B	D	E	F	A	C

Constructive parameter: a mutation percentage (p_m)

The Genetic Algorithm

Paretian Simple Genetic Algorithm (P-SGA)

IdProduct	Amount	IdSupplier	UnitPrice
1	2	1	10000
		2	12000
		3	0*
2	2	1	18000
		2	15000
		3	20000
3	3	1	0*
		2	5000
		3	7000



Available funds: $50,000

Spent funds: $39,000

$f_1 = 0.57$

$$f_2 = 1 - \frac{12000+15000+5000+7000}{87000} = 0.55$$

$z = 0.57/2 + 0.55/2 = 0.56$ (56%)

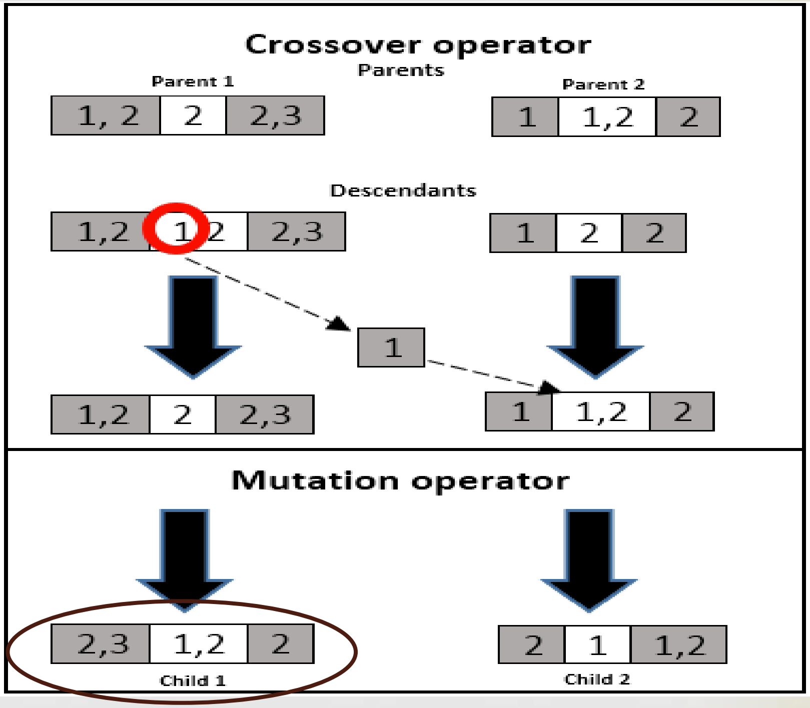
Experiments and results

Paretian Grouping Genetic Algorithm (P-GGA)

IdProduct	Amount	IdSupplier	UnitPrice
1	2	1	10000
		2	12000
		3	0*
2	2	1	18000
		2	15000
		3	20000
3	3	1	0*
		2	5000
		3	7000

Available funds: $50,000

Spent funds: $50,000



$f_1 = 0.71$

$$f_2 = 1 - \frac{12000+0+18000+15000+5000}{87000} = 0.42$$

$z = 0.71/2 + 0.42/2 = 0.65$ (65%)

Experiments and results

Input instances

Order	Quantity of products	Mínimal Prices	Maximal Prices	Funds
1	126	14.00	10,999.00	25,000.00
2	123	73.00	60,000.00	50,000.00
3	63	29.00	120,000.00	40,000.00
4	146	99.90	15,980.00	65,000.00
5	70	3.00	60,000.00	30,000.00
6	194	56.90	20,000.00	80,000.00
7	128	75.00	18,799.00	75,000.00
8	119	95.00	18,000.00	55,000.00
9	108	3.00	88,996.00	48,000.00
10	126	14.00	11,499.00	40,500.00

GA configuration

$N = 30$

p_c=0.005

p_m=0.001

Six tests executed: 1000, 5000, 10000, 15000, 20000 and 30000 iterations

Experiments and results

Results

Algorithm / Métric	ACS	P-ACO [1]	P-ACO [2]	P-SGA	P-GGA
Computation time (segs)	10.9	17.51	29.10	10.5	17.7
z values	0.86	0.88	0.90	0.90	0.98
Pearson's Correlation Coefficient (f_1 - f_2)	-0.21	-0.94	-0.96	0.26	-0.99

ACS: Ant Colony System (Delgado 2014)

P-ACO: Paretian Ant Colony Optimization (2 variants) (Delgado 2015)

P-SGA: Paretian Simple Genetic Algorithm

P-GGA: Paretian Grouping Genetic Algorithm

Experiments and results

- Input instance

```
PROBLEM_NAME: PURCHASING_SCHEDULING
INFO_PRODUCTS:
1 1   JACINTO PEREZ  1   DESK              1   OFFICE DEPOT
1 1   JACINTO PEREZ  2   TABLET            2   HUAWEI
1 1   JACINTO PEREZ  3   HDMI CABLE        3   MASTER COMPUTER
1 1   JACINTO PEREZ  4   AJAX IN J2SEE     4   PRENTICE HALL
1 1   JACINTO PEREZ  5   RAM MEMORY        5   KINGSTON
1 1   JACINTO PEREZ  6   USB MEMORY        5   KINGSTON
1 1   JACINTO PEREZ  7   PRINTER           6   HEWLETT PACKARD
1 1   JACINTO PEREZ  8   KEYBOARD          7   MANHATTAN
1 1   JACINTO PEREZ  9   DVD WRITER        8   SAMSUNG
1 1   JACINTO PEREZ  10  DESKTOP COMPUTER  9   DELL
1 1   JACINTO PEREZ  11  LED LIGHTS        10  PHILLIPS
1 1   JACINTO PEREZ  12  OFFICE CHAIR      1   OFFICE DEPOT
2 1   JACINTO PEREZ  13  LADDER            11  TRUPPER
2 1   JACINTO PEREZ  14  LAPTOP COMPUTER   12  APPLE
2 1   JACINTO PEREZ  15  NO BREAK          9   DELL
2 1   JACINTO PEREZ  16  LED PROJECTOR     13  LG
3 2   ELSA GALINDO   17  CHAIR             1   OFFICE DEPOT
3 2   ELSA GALINDO   18  LAPTOP COMPUTER   9   DELL
3 2   ELSA GALINDO   19  SOLID STATE DISK  5   KINGSTON
```

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```
PROBLEM_NAME: PURCHASING_SCHEDULE
PRODUCTS_CATALOGUE:
1     4200.00    1     1    1     1
2     1000.00    2     1    4     1
3     25.00      3     1    2     1
4     8000.00    4     1    3     1
5     1500.00    5     1    10    1
6     899.00     6     1    7     2
7     6440.00    7     1    12    3
8     179.00     8     1    9     1
9     185.00     9     1    6     2
10    7100.00    10    1    8     1
11    500.00     11    1    5     3
12    1800.00    1     1    11    2

INFO_FUNDS:
1     1     25000

INFO_INV_CICLE:
1     1

ORDERS:
1
      1
            1     1
            2     1
            3     7
            4     1
            5     2
            6     2
            7     1
            8     4
            9     6
```

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Experiments and results

A Purchasing plan

IdOrder	IdPuerchaser	IdProduct	IdSupplier	UnitPrice	RequiredUnits	SuggestedUnits	TotalCosts	AvailableFunds
1	1	1	1	4200	1	1	4200	
		2	2	1000	1	1	1000	
		3	3	25	7	4	100	
		4	4	8000	1	1	8000	
		5	5	1500	2	1	1500	
		6	6	899	2	1	899	
		7	7	6440	1	1	6440	
		8	8	179	4	2	358	
		9	9	185	6	1	185	
		10	10	7100	1	0	0	
		11	11	500	2	1	500	
		12	1	1800	1	1	1800	
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Conclusions and Future Works

- A Paretian Aproach was designed to adapt the Genetic algorithm metaheuristic to solve efficiently the Purchasing Scheduling Problem.

- Pearson's correlation coefficient of -0.99 and the *z* value of the P-GGA (0.98 or 98%) demonstrate that Purchasing Scheduling can be classified as a clusering problem.

Future Works

- Exploration of the remaining solution space (looking for the $z = 1$ or 100%)

- The solver can be included in an Inventory System to give it a smart feature, like an Enterprise Resource Planning System (ERP).

References

- Delgado Orta, J.F. et al. An ant Colony System Metaheuristic for solving a Bi-Objective Purchasing Scheduling Problem. Journal Research in Computing Science. Vol. 82. pp. 21-30 ISSN: 1870-4069. 2014.

- Delgado Orta, J.F. et al. Solving a Bi-Objective Purchasing Scheduling Problem with Constrained Funds using Pareto Optimization. Journal Research in Computing Science. Vol. 104. pp. 41-50 ISSN: 1870-4069. 2015.

For your attention

Thank you very much

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