Appendix E

GENETIK
Genetic algorithm for the sizing cases research

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Abstract

GENETIK is a CNES internal tool which use genetic algorithm for sizing cases research. A first development phase has been started in 2005, with a validation on simple cases.
In 2009, a second development and validation phase has led to an optimized tool in term of results and methodology.
The objectives of the presentation are the following:

- Describe the principles of genetic algorithms,
- Focus on optimization in GENETIK in term of algorithm operators and methodology,
- Present validation cases and results.

GENETIK :

Genetic algorithms for the sizing cases research

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23rd European Workshop on Thermal and ECLS Software, 6-7 October 2009, ESA/ESTEC

Agenda

- Context of the study
- Genetic Algorithms
  - Presentation
  - Operator optimization
- Example
- Conclusion

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Context of the study

- New project → complex orbit and many possible attitude (random attitude for example)

  → More complicated to determine the dimensioning case for thermal analysis

- Use of genetic algorithms for sizing cases research → training period in 2005 has led to a first internal tool GENETIK
- 2009 : new training period to
  - Improve knowledge on genetic algorithms
  - Optimize GENETIK
  - Validate the internal tool on simple cases

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Genetic Algorithms - Presentation

- Search technique used to find solutions to optimization problems
- Technique inspired by evolutionary biology such as inheritance, mutation, selection, and crossover.
- Vocabulary :
  - Gene : parameter of the problem (ex. : altitude of the satellite)
  - Individual : combination of genes
  - Population : set of individual
  - Fitness : evaluation function to optimize (most of the time temperature)

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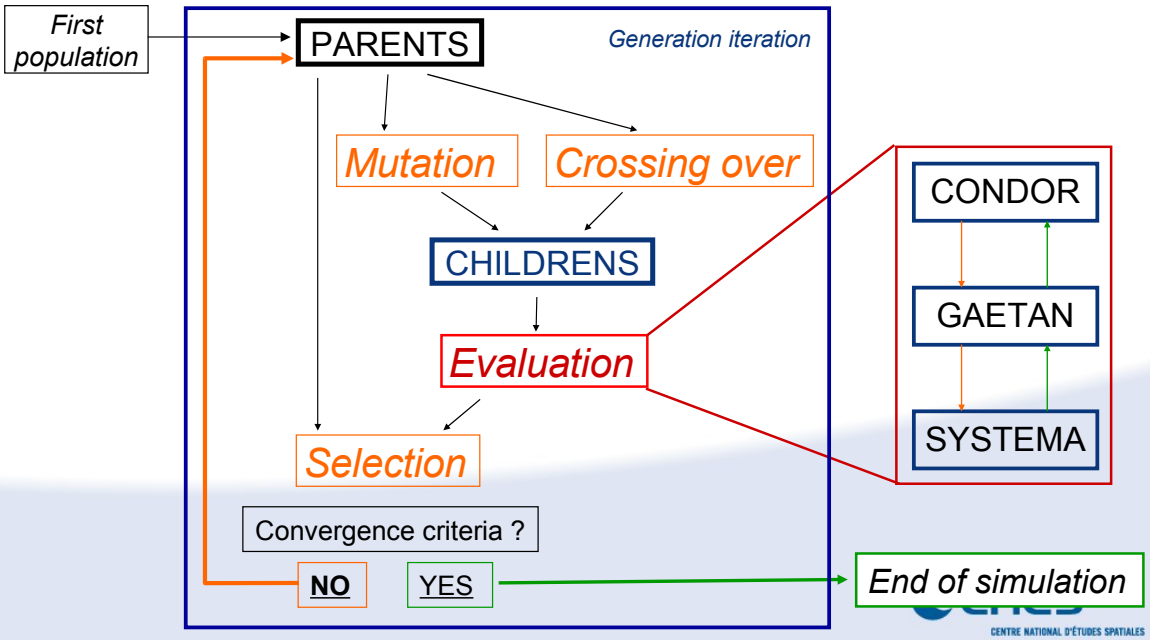
Genetic Algorithms - Presentation

- General architecture of the algorithm :



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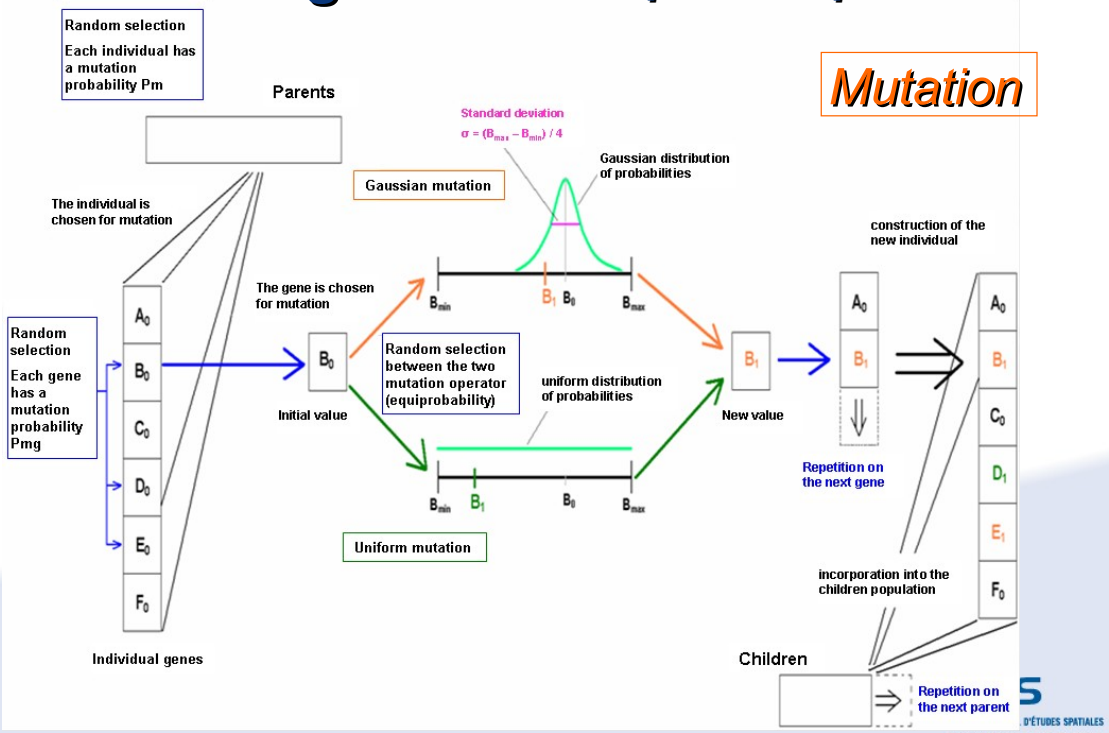
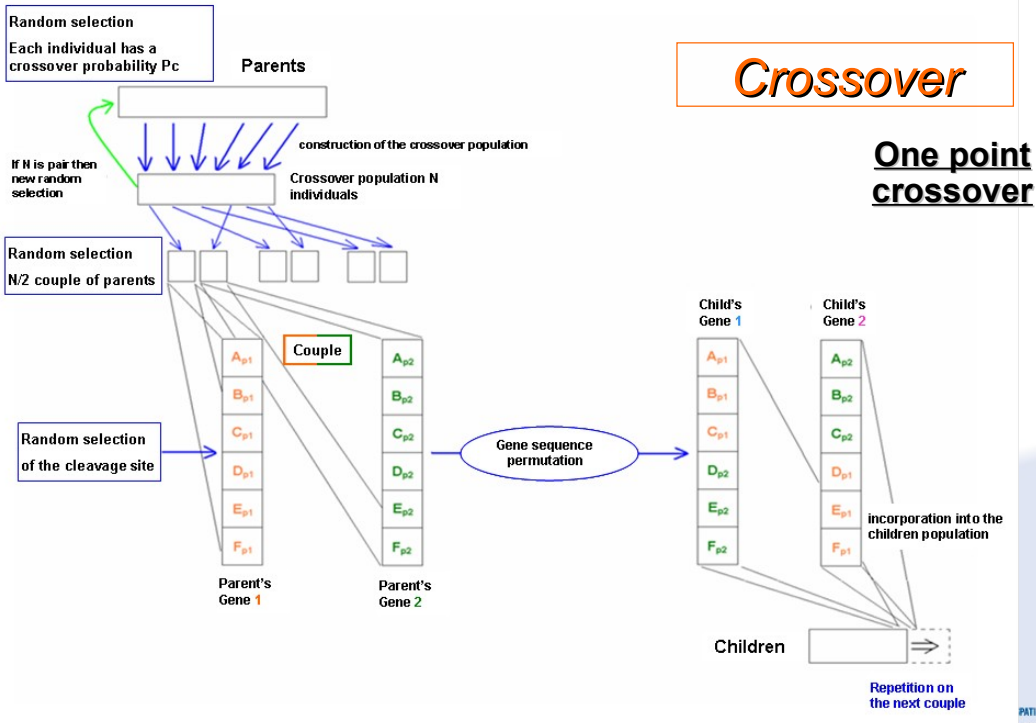
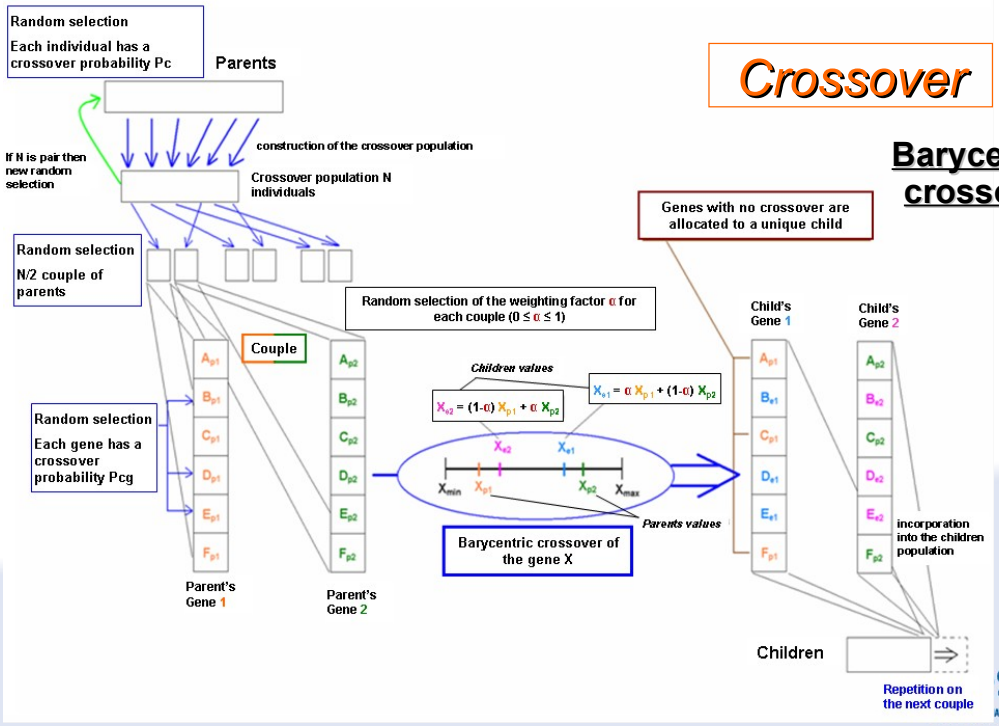
Genetic Algorithms - Operator optimization



Genetic Algorithms - Operator optimization



Genetic Algorithms - Operator optimization



Genetic Algorithms - Operator optimization

SELECTION : Selection

Keep the **best** individuals to converge but keep **diversity** to avoid convergence to a local optimum

➡ Two different ways :

- elitism

- roulette wheel

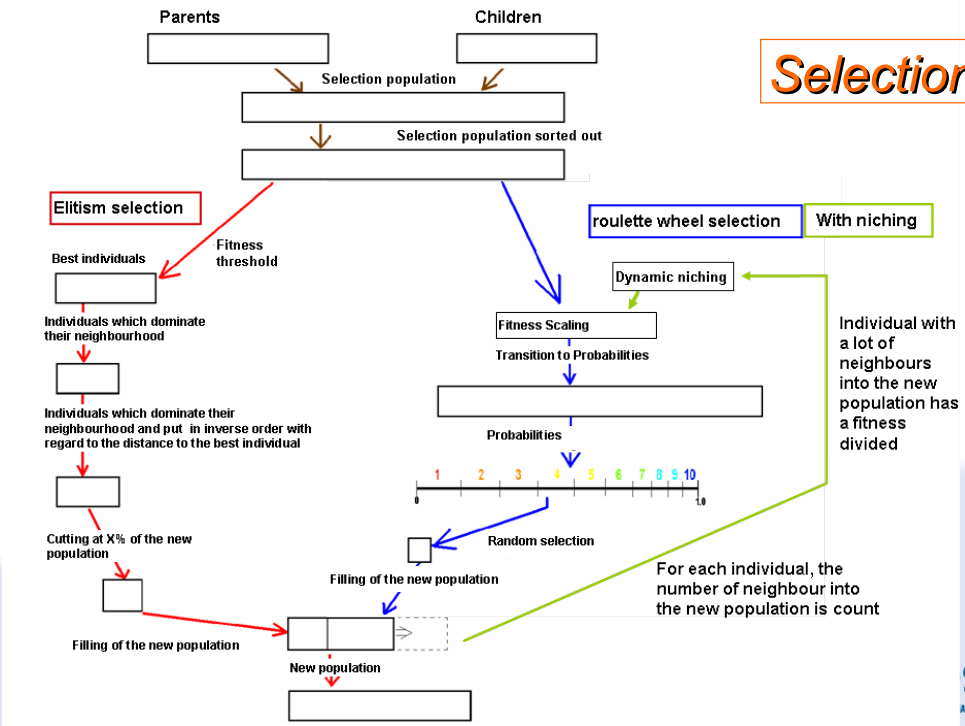
WHAT IS A INTERESTING INDIVIDUAL FOR SELECTION :

- An individual with a good fitness
- An individual which is “far” from the other good individuals
- An individual which dominate a “zone” in the search space

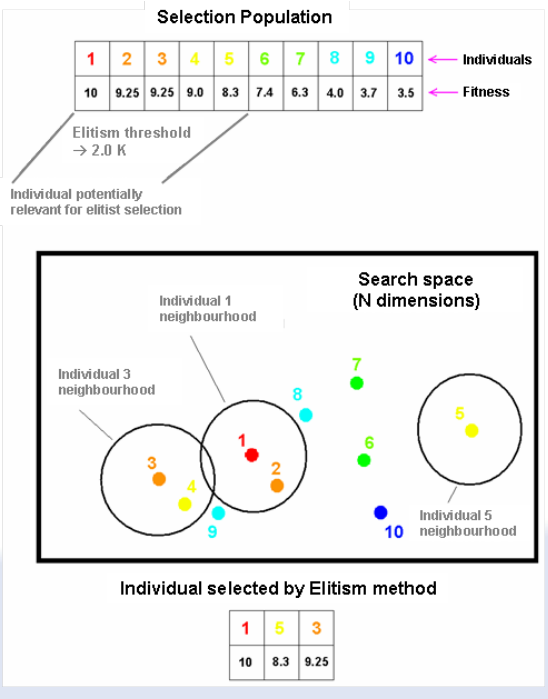
➡ Elitism threshold on fitness

➡ Threshold on each gene of the individual

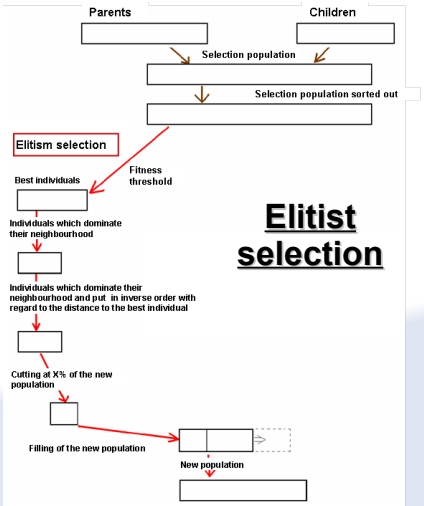
Genetic Algorithms - Operator optimization



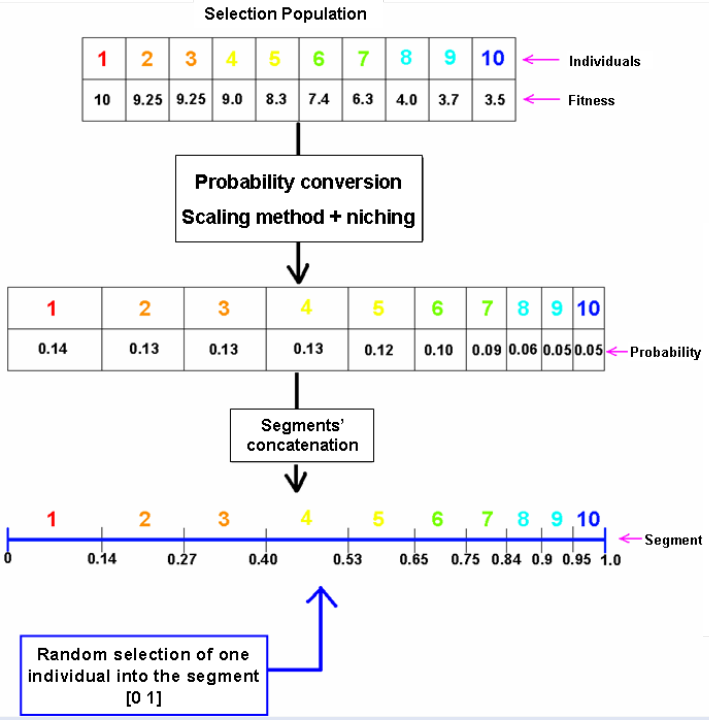
Genetic Algorithms - Operator optimization



Selection

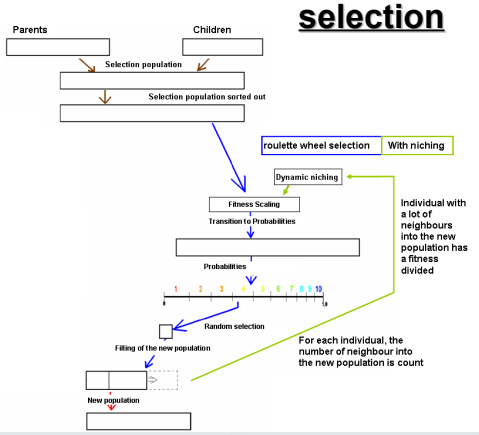


Genetic Algorithms - Operator optimization



Selection

Roulette wheel selection



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Example

- On a simple geometry (cube with anisotropic conductivity)
- Sun synchronous orbit
- Tested parameters :
  - Altitude : [700 ; 900] km
  - Solar hour at ascending node : [06h00 ; 12h30]
  - Albedo : [0.35 ; 0.50]
  - Attitude vector 1 : { z, -z }
  - Attitude vector 2 : {x, -x, y, -y}
  - Day of the year : [1 ; 365]

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Example

- Protocol
  - First simulation :

    IDENTIFICATION of the important gene – optimization of the selection parameter
  - Second simulation

    CONFIRMATION of all the local optima
  - Third and last simulation

    LOCAL EXPLORATION around the local optima to determine the global one

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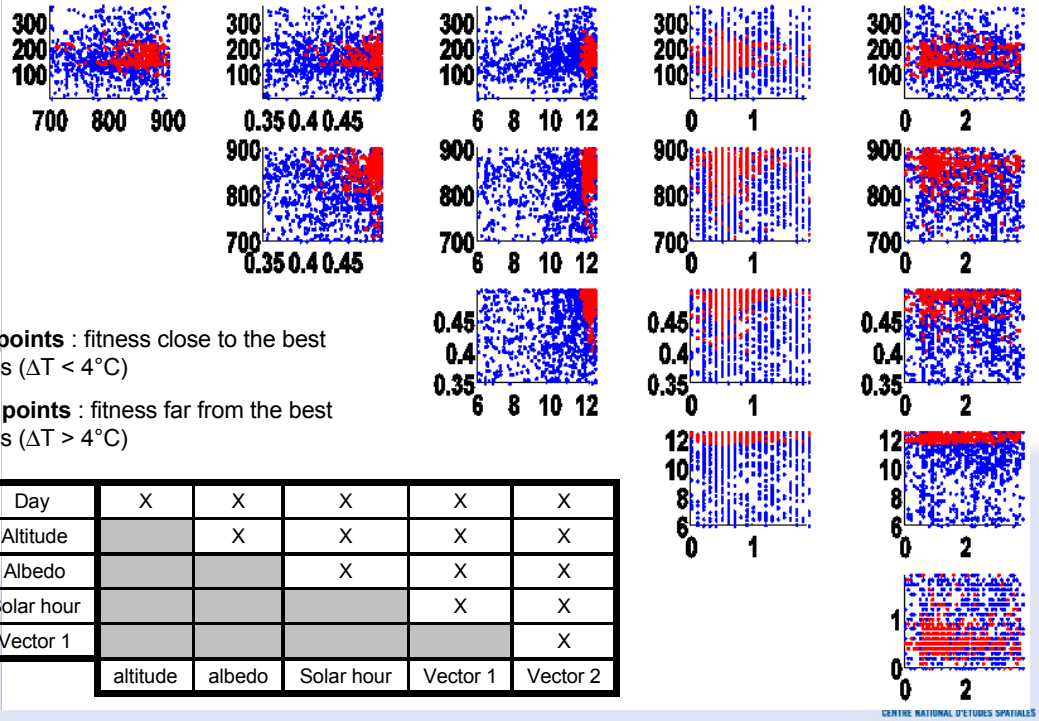
Example – first simulation

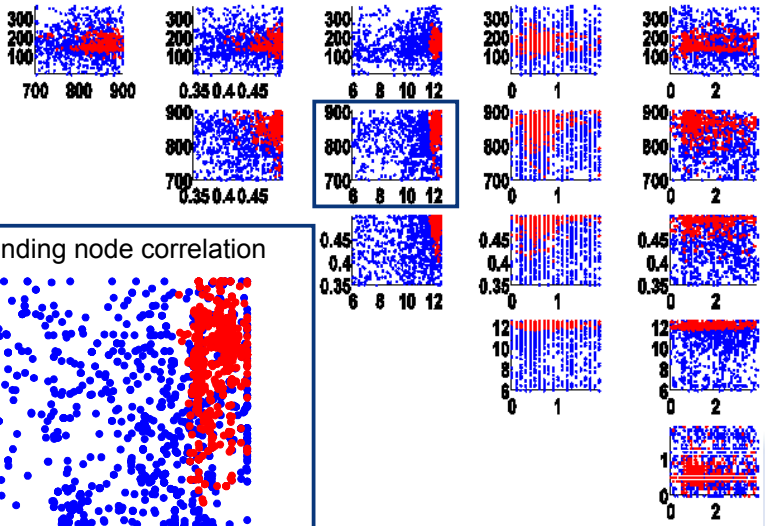


Red points : fitness close to the best fitness ($\Delta T < 4°C$)

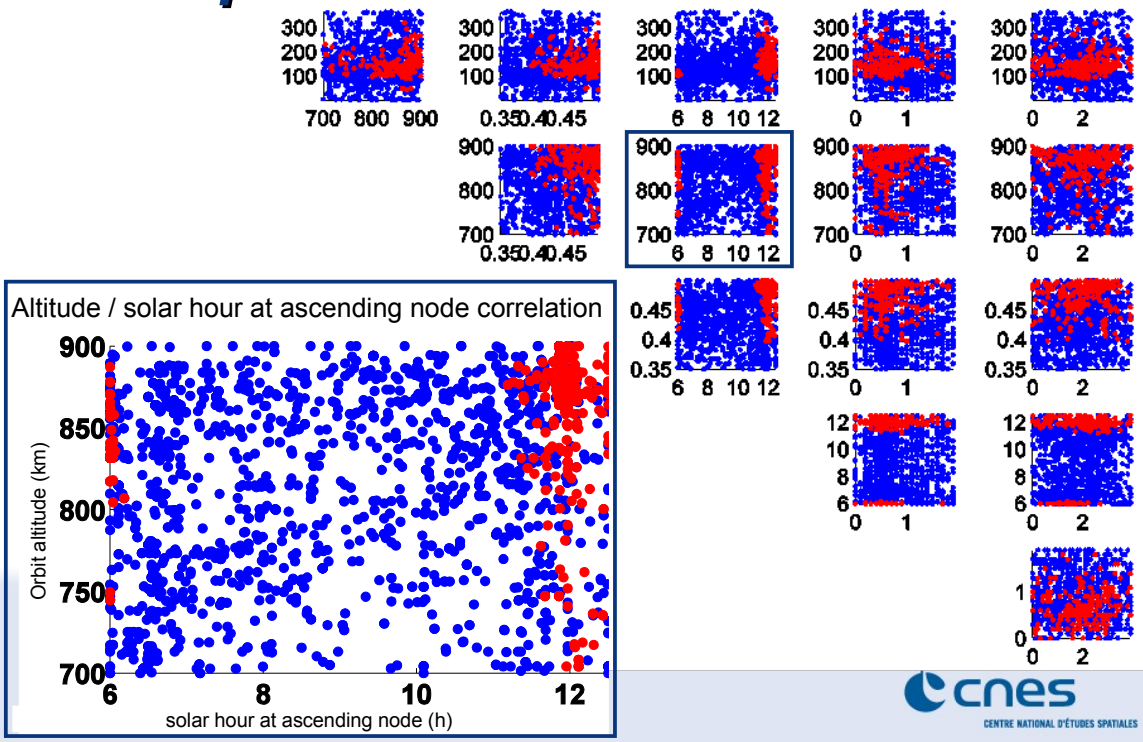
Blue points : fitness far from the best fitness ($\Delta T > 4°C$)

Day	X	X	X	X	X
Altitude		X	X	X	X
Albedo			X	X	X
Solar hour				X	X
Vector 1					X
	altitude	albedo	Solar hour	Vector 1	Vector 2

Example – first simulation



Example – second simulation



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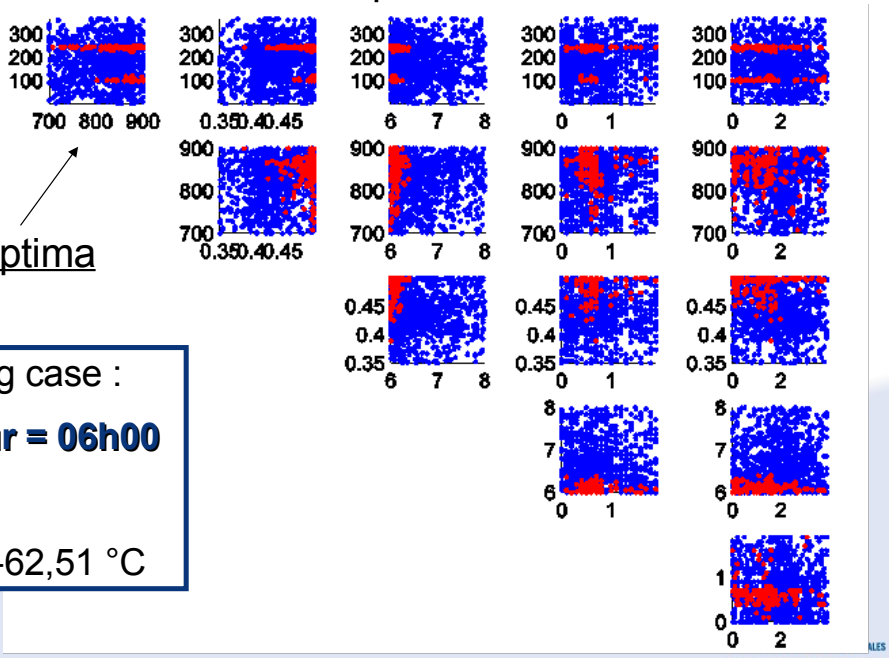
Example – third simulation

Local simulation on the two optima :



New local optima

Final sizing case :

Solar hour = 06h00

Day = 242

Fitness = -62,51 °C

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Conclusion

- GENETIK is today optimized
- Validation on a simple case → definition of a user protocol
- Simulation duration → ~50 to 70h on one processor
- New development to allow a continuous exploration for attitude
- After a complete validation, integration in GAETAN V5

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