Scilab and modeFRONTIER integration

Optimization of a pipe network for water distribution

modeFRONTIER®
the multi-objective optimization and design environment

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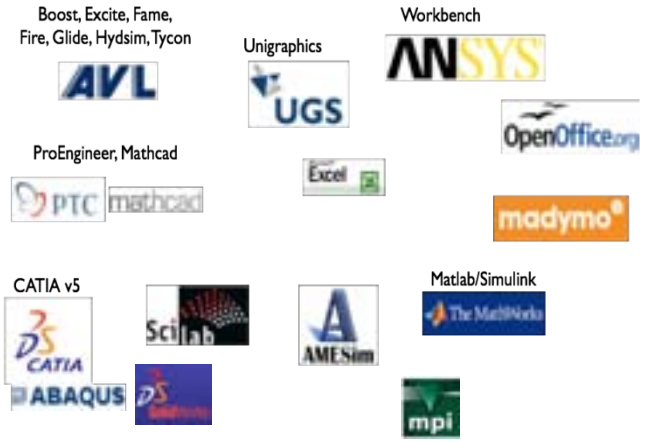
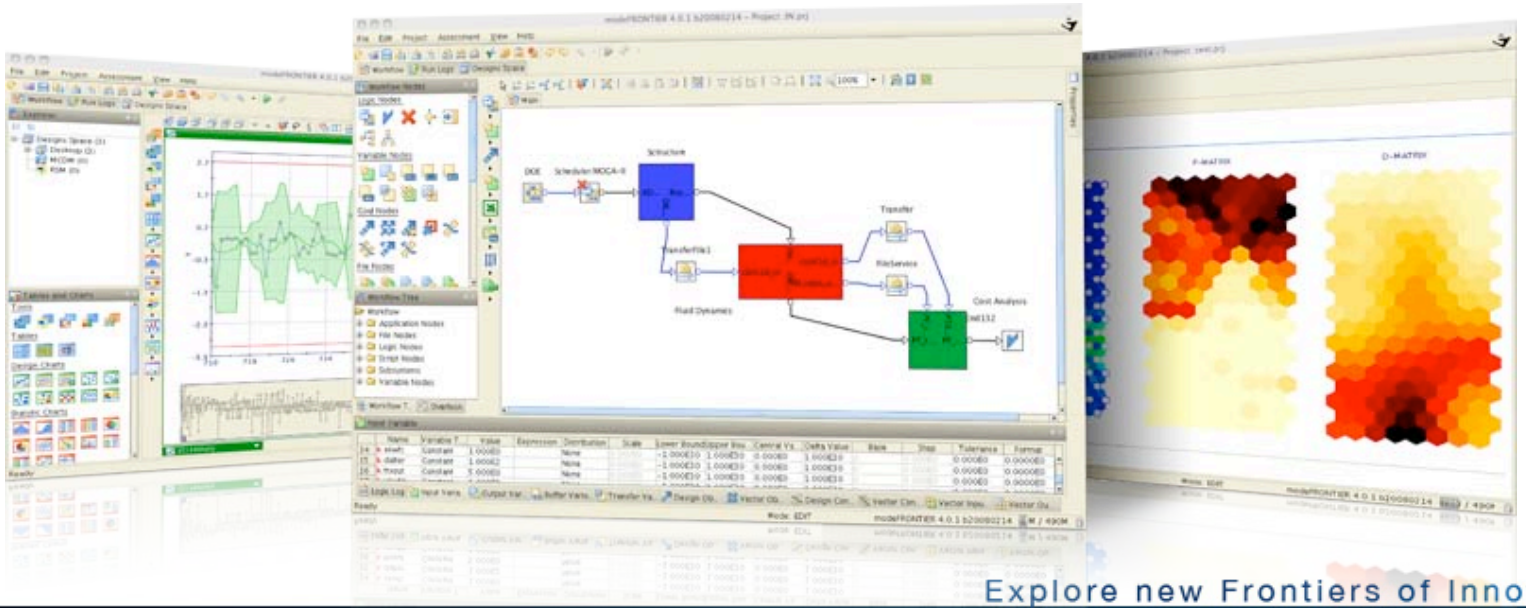
About modeFRONTIER…



- Integrate CAE/Solver tools in the design process
- Optimization Algorithms and DOEs engines
- Decision support and statistical analyses



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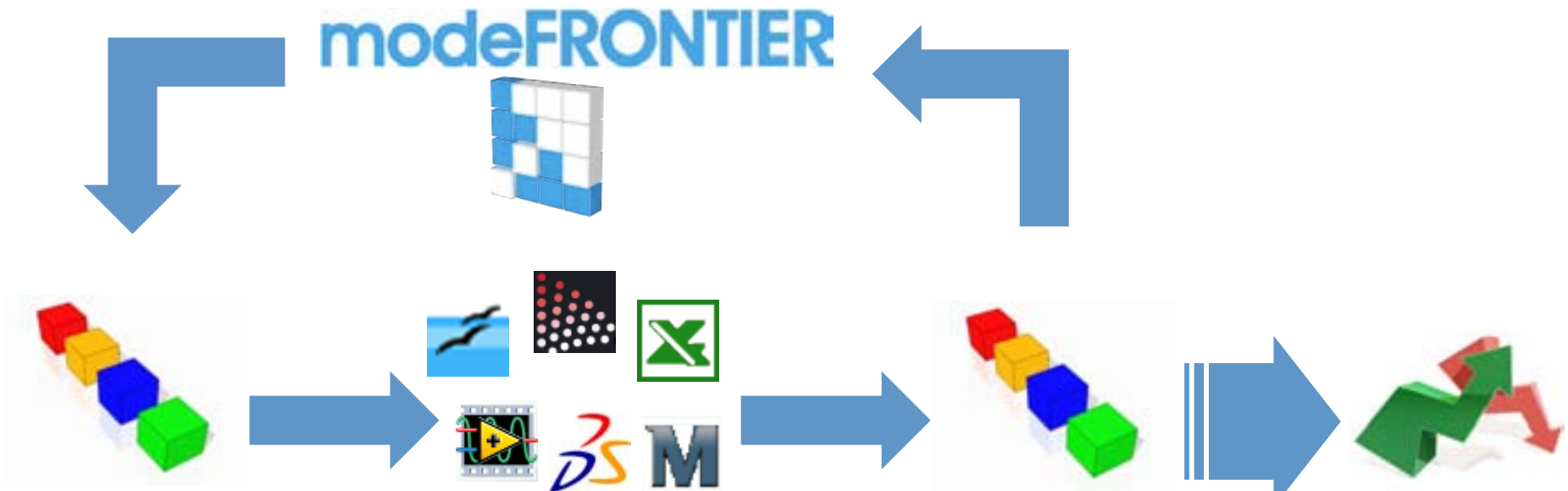
Software in the loop



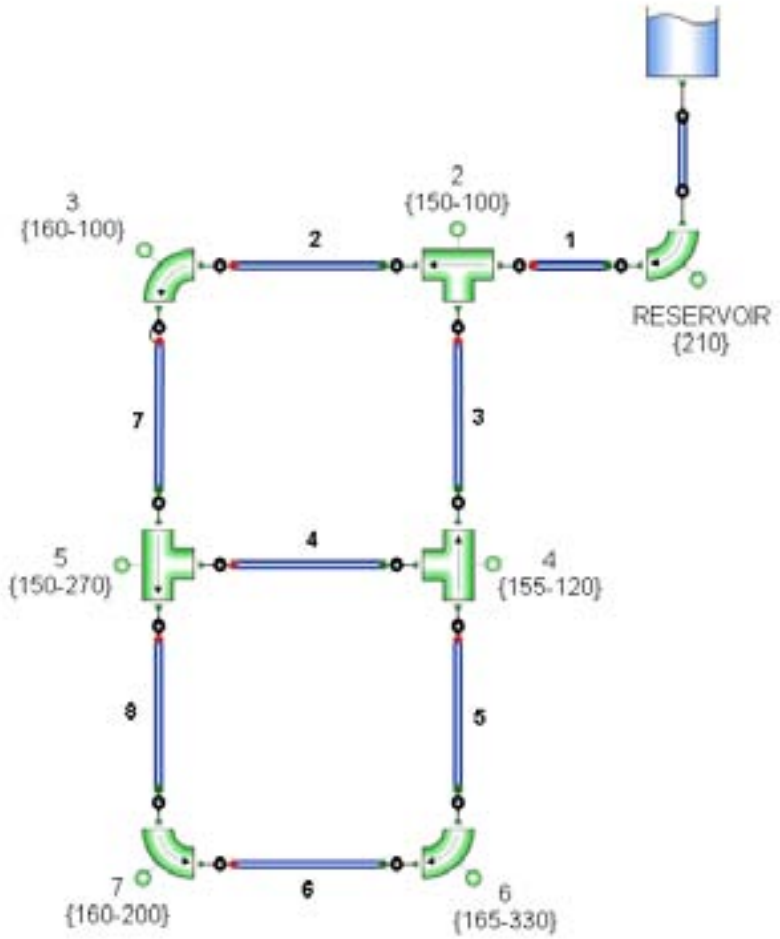
Input Variables:
Entities defining the design space.

The Solver Box:
(Solvers, Worksheets, CAE tools in any combinations)

Output Variables:
Measures from the system

Aiming at the **Optimum**

Presentation of the problem



- System where a reservoir (1) feeds 6 nodes (2–7) with water through a piping network
- The height of the reservoir and each node is provided, as is the demand at each node

Presentation of the problem

D(inches)	Cost/meter($)
1	2
2	5
3	8
4	11
6	16
8	23
10	32
12	50
14	60
16	90
18	130
20	170
22	300
24	550

Commercially available pipes sections and associated costs

- The 8 pipes in the system are all 1000 meters long, and all have the same Hazen-Williams loss coefficient of 130
- The diameters of the pipes vary according to standard values obtained from a catalog list, each diameter having an associated cost

Optimization goals

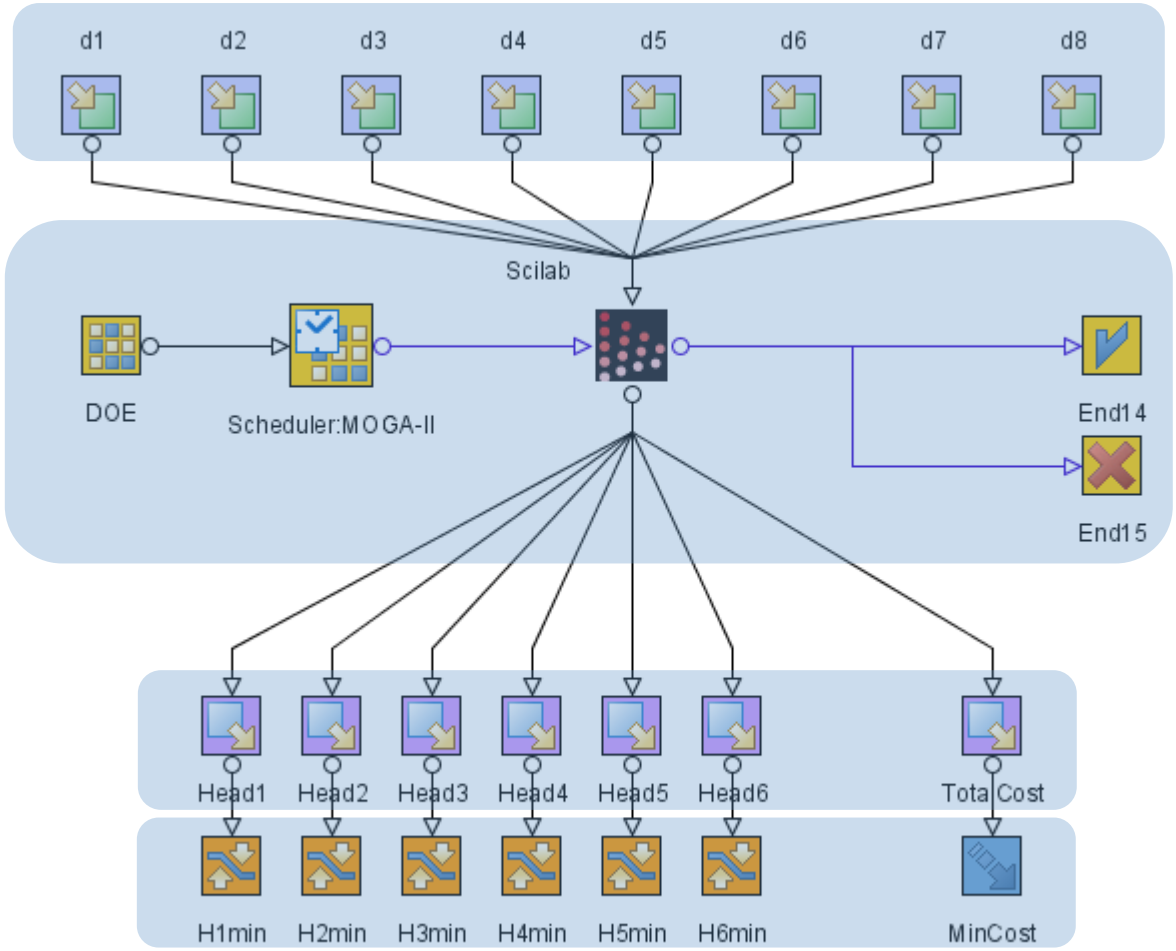
- The objective is to **minimize the overall network cost**

- An added constraint is that the minimum nodal head requirement for each node be 30 meters.

- As there are 8 pipes in the system, and 14 available diameters for each, there are *148 possible configurations*

- Ideally suited to the application of optimization algorithms

The modeFRONTIER Project



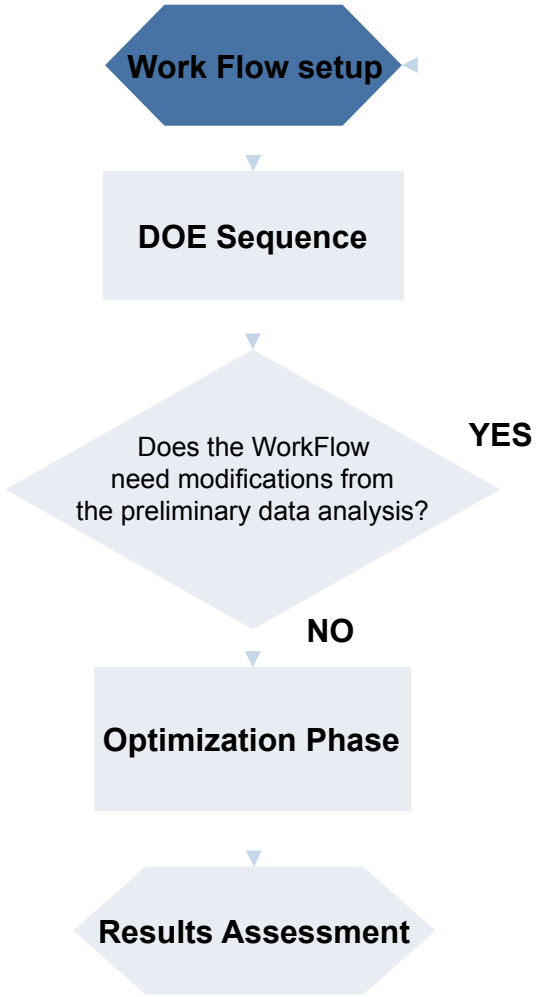
The Input Variables

Logic Flow set up

The Output Variables

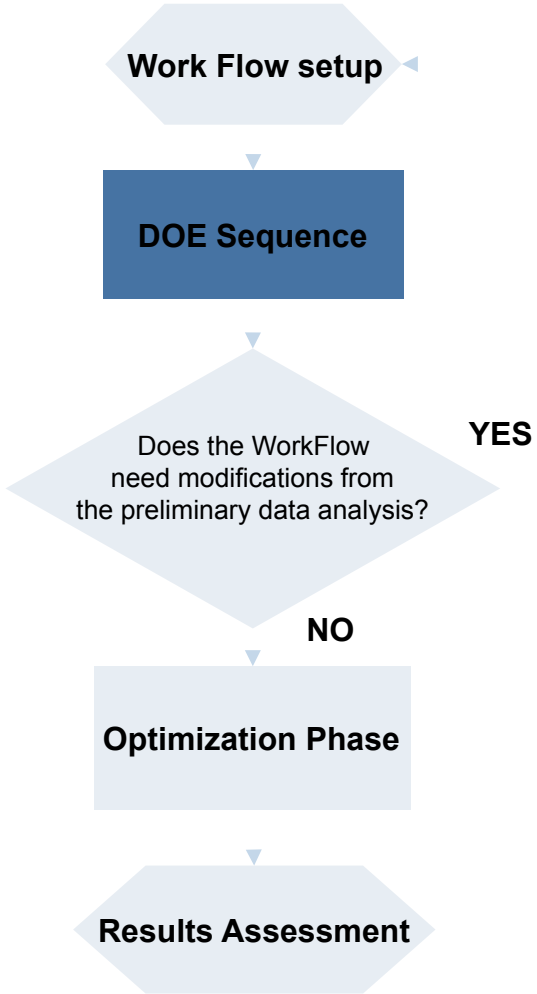
The Constraints and the Goal

The modeFRONTIER Work flow



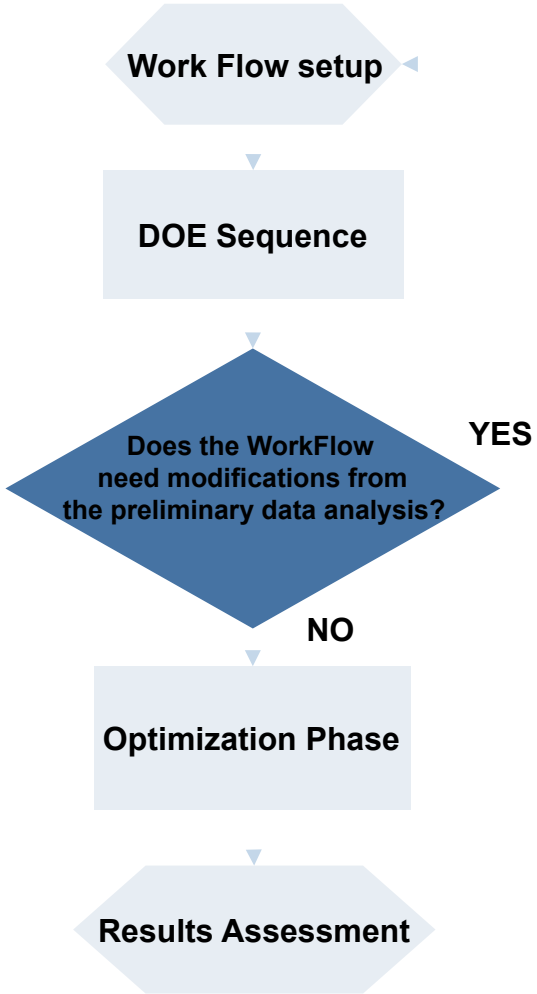
- Design parameters definition:
  - continuous variables, such as geometric dimensions
  - discrete variables, such as the number of an item in a catalogue of off-the-shelf components.
  - mixture of continuous and discrete variables
- Objective Functions definition
- Constraints imposition
- **Scilab script entry and modification**
- Logic conditions:
  - Conditional switch
  - Logic end
  - Synchronizer

The DOE Sequence



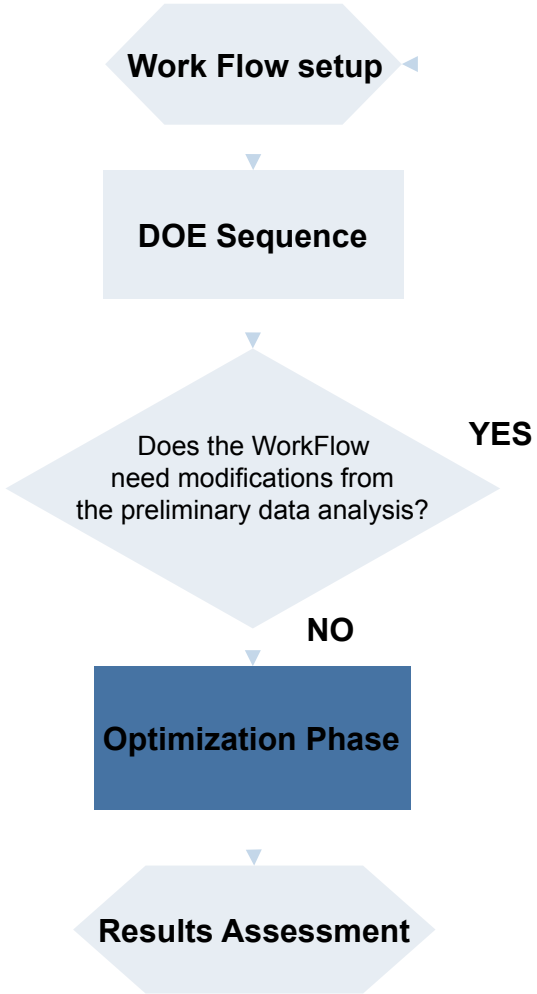
- The Design of Experiments idea:
  - Preliminary exploration of the design space
  - Provide an initial population of candidate designs
  - Let the user build some understanding of the behavior of the objectives and constraints, prior to deciding what further search method to use

The DOE check up



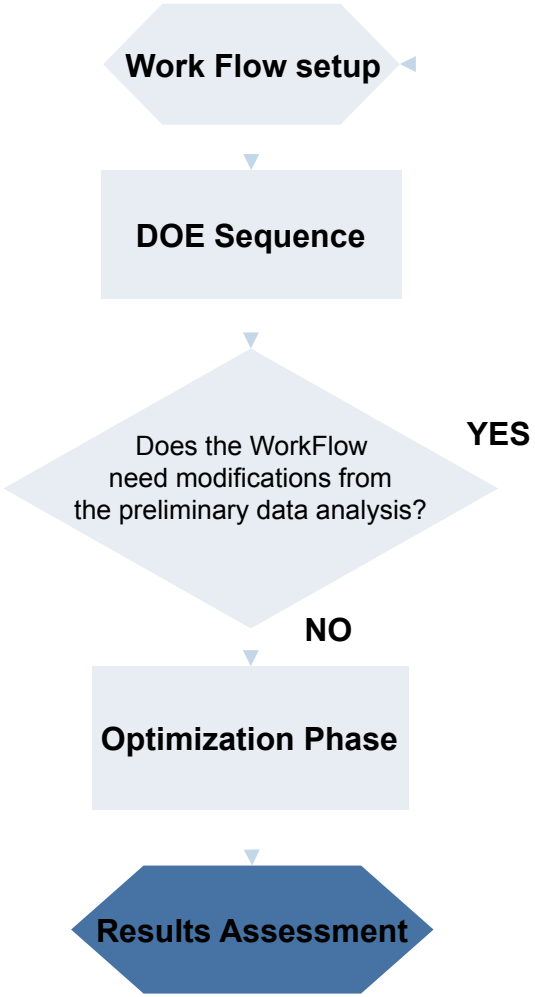
- Eliminate the redundant Input Variables
- Reduce the number of objectives
- Turn objectives into constraints
- …

The Optimization



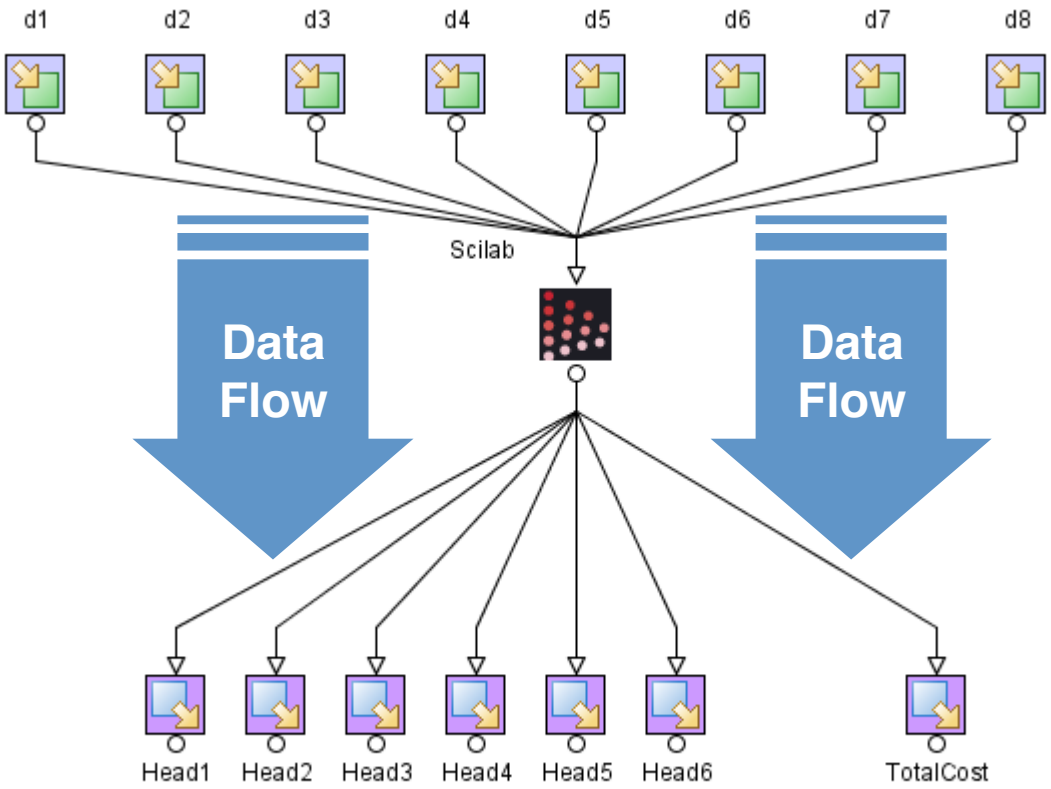
- Choose the proper optimization algorithm to search for the global maximum point
- Modify optimum search strategy by using different optimization strategies
- Apply the RSM tool as mathematical interpolation function to speed up the run
- Use the MCDM tool by applying the concept of utility function

The Project Results



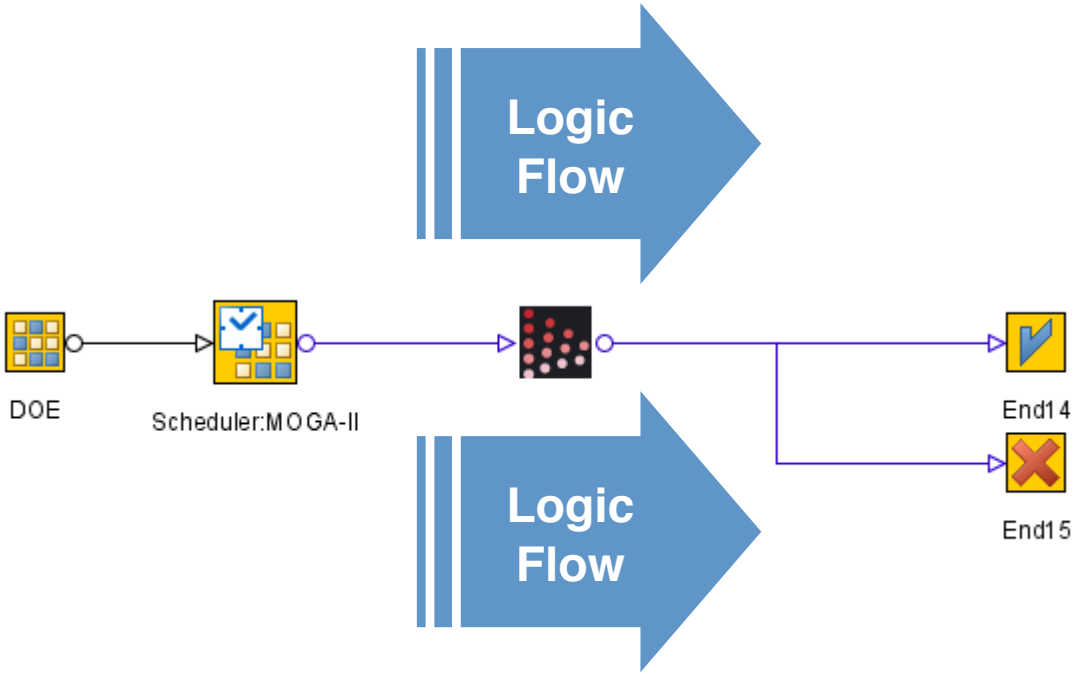
- Results assessment by means of:
  - Selection of best design(s) among the optimal (Pareto) set
  - Graphic post-processing:
    - Optimization history charts
    - Scatter charts
    - Bubble charts
    - Parallel chart
    - Statistical charts

The data flow



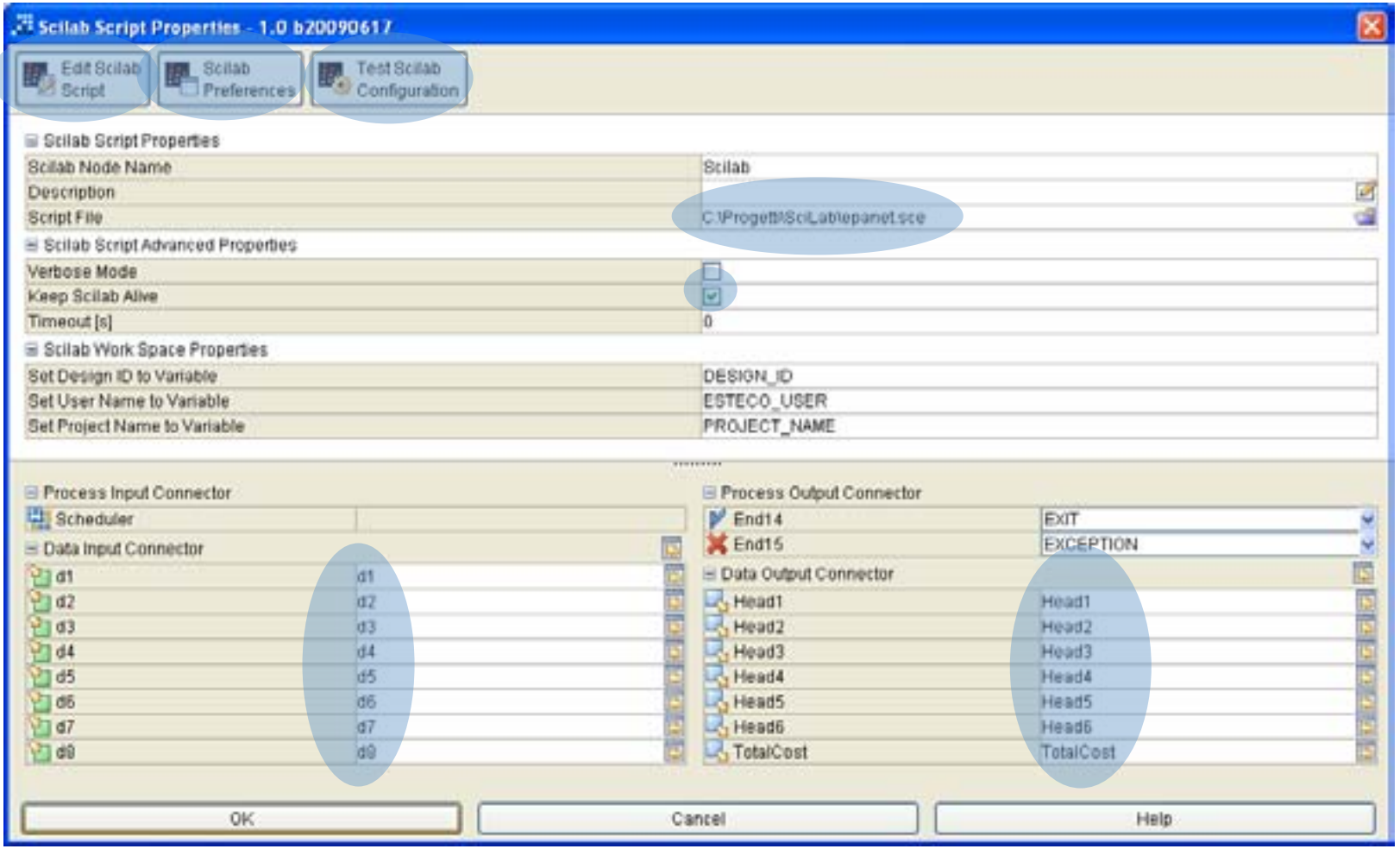
- Assign a specific value for each Input Variable (pipe diameter dimension)
- Run the Scilab Script to compute the nodal hydraulic head
- Mine the Output Variables from the Scilab environment

The logic flow

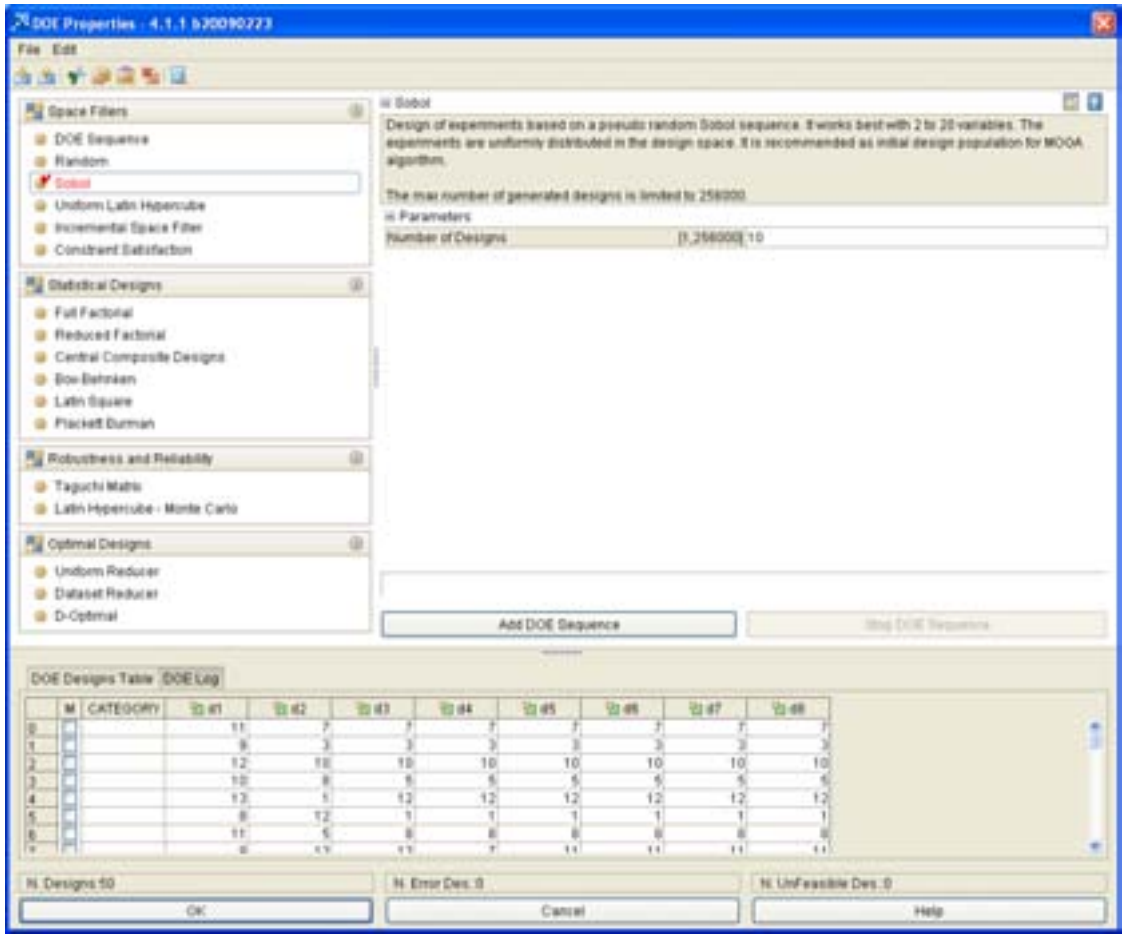


- Assign a specific DOE sequence
- Apply a Scheduler (DOE only or Optimization phase)
- End up the logic flow for the design evaluation process

Scilab integration

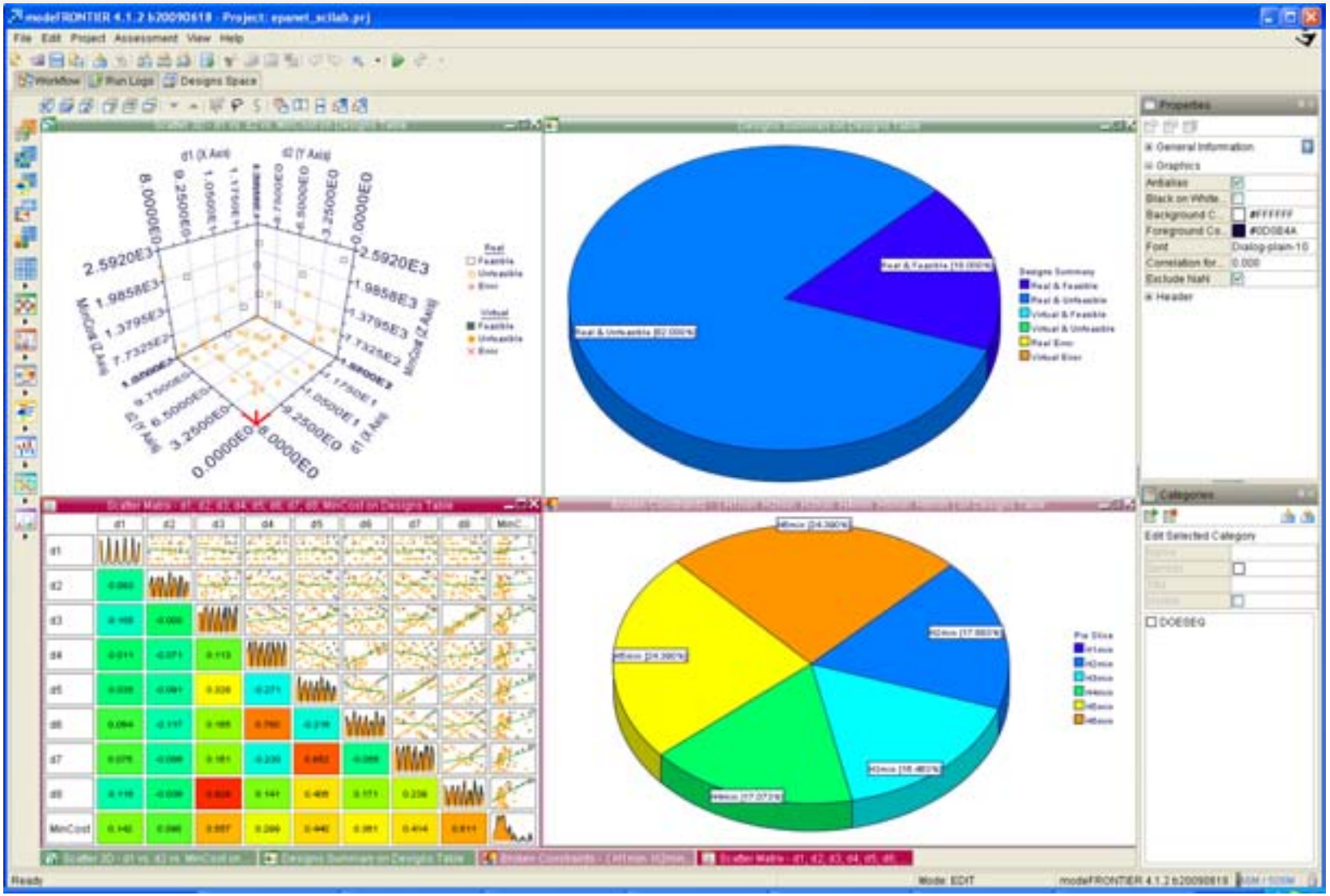


DOE – The algorithms



- Different types of algorithms to generate an effective *Design of Experiments* (DOE) available
- The **Sobol** algorithm has been used to generate 50 initial designs

DOE check up



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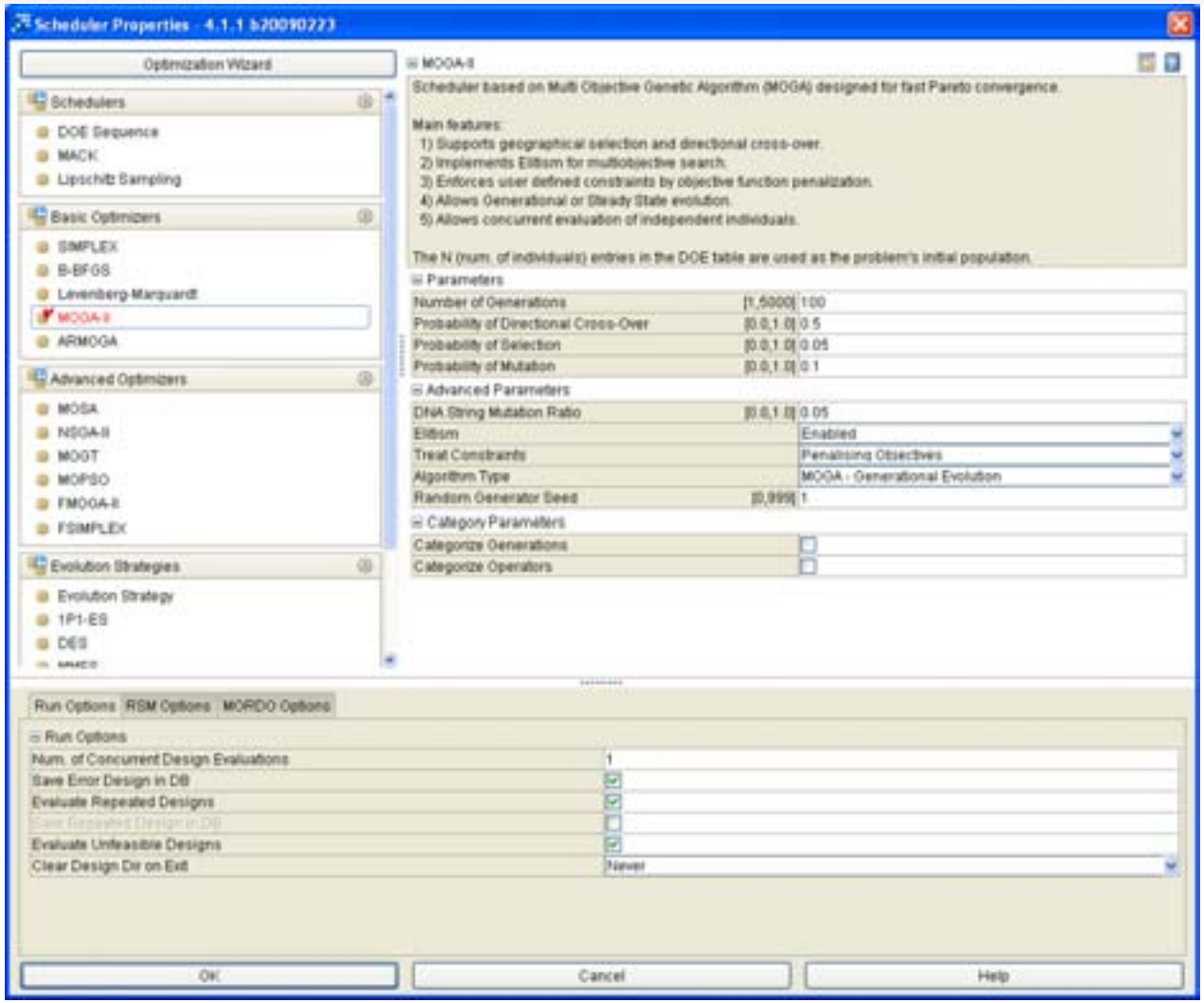
DOE check up

- The **correlation** is a number (between -1 and 1) describing the degree of relationship between two variables
- The correlation is a measure of the linear association
- If you want to have a well balanced DOE the correlation between input variable should be close to zero.

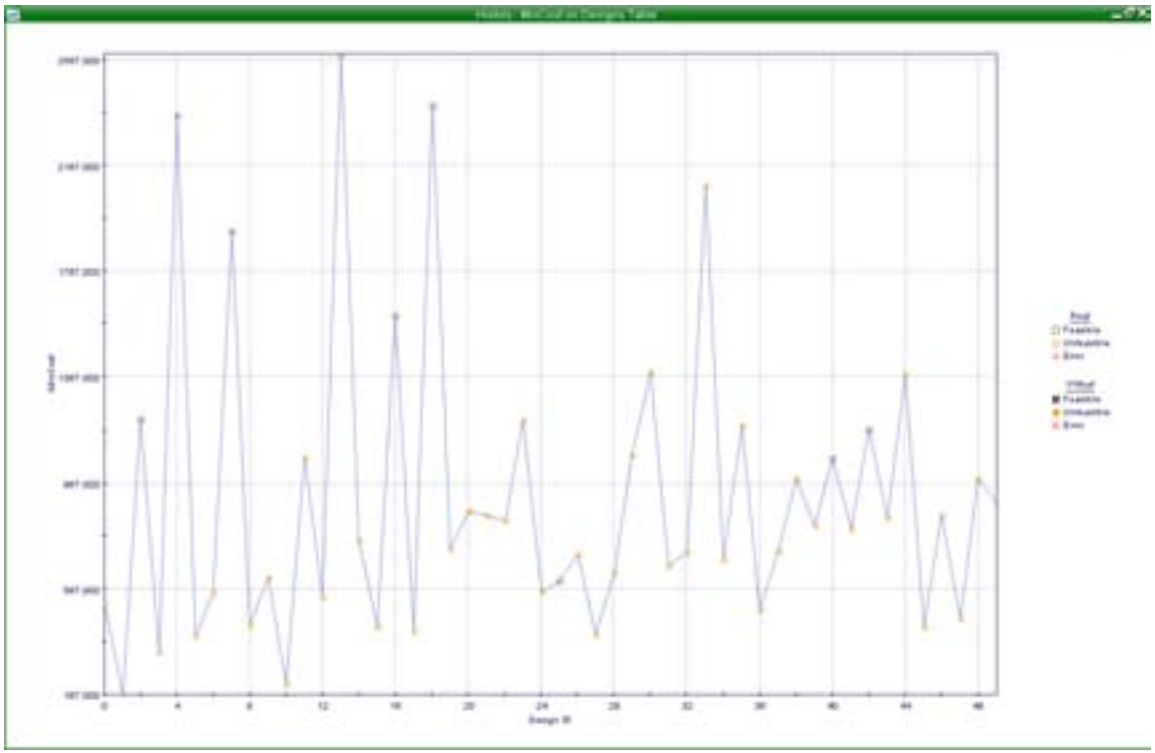
The Optimization Phase – The algorithms



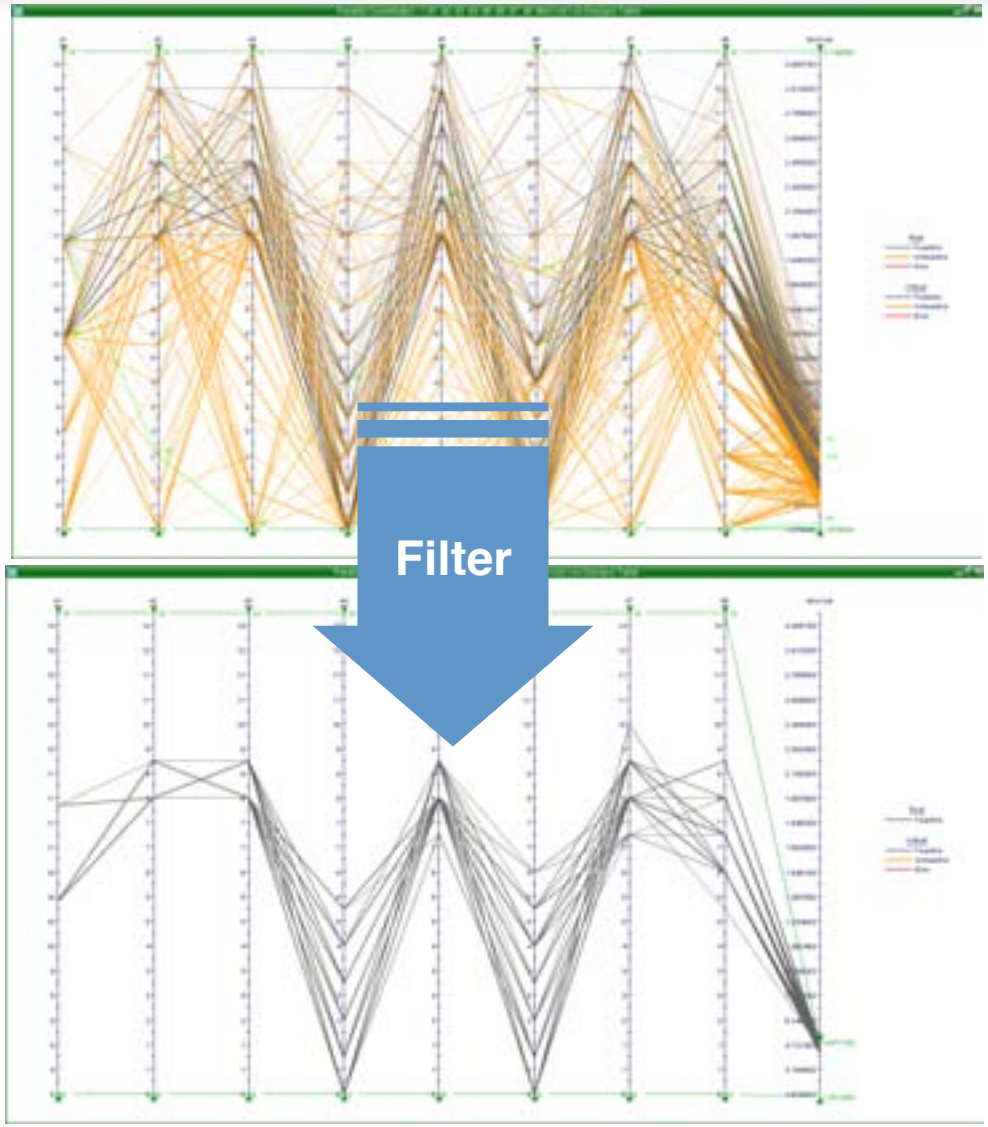
- Different types of algorithms to perform a design optimization
- The **MOGA-II** algorithm has been used to generate 50 generations composed of 50 designs

The Optimization Phase – Monitoring

- The history plot:
  - A two dimensional plot
  - The quantities are plotted as a function of the Design ID
  - In a mono-objective problem is possible to see that the optimization algorithms evolve the starting points generating designs with better values.

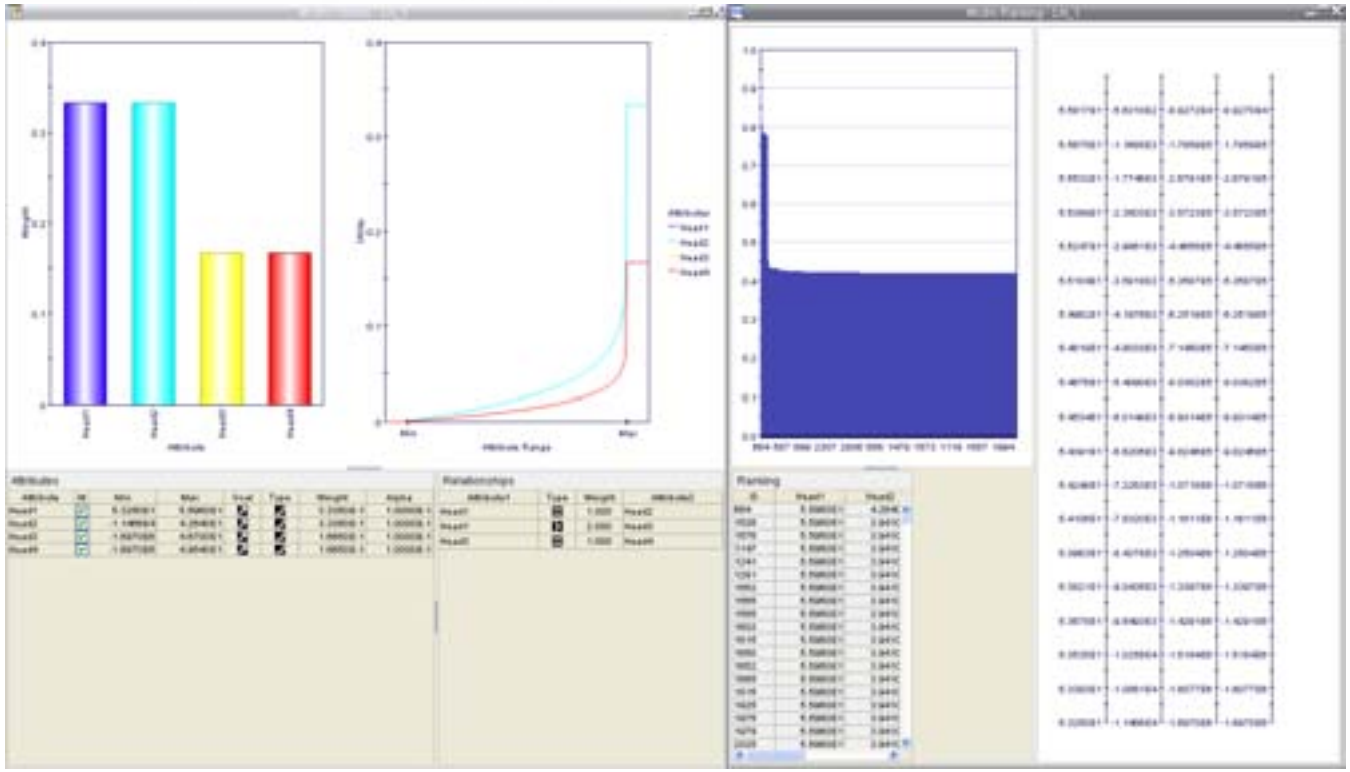


Data Analysis



- A method of displaying multivariate data.
- It is useful to quickly evaluate designs whose variables are in a particular range
- It allows the creation of a filter for the selection of the most interesting solutions in the database.

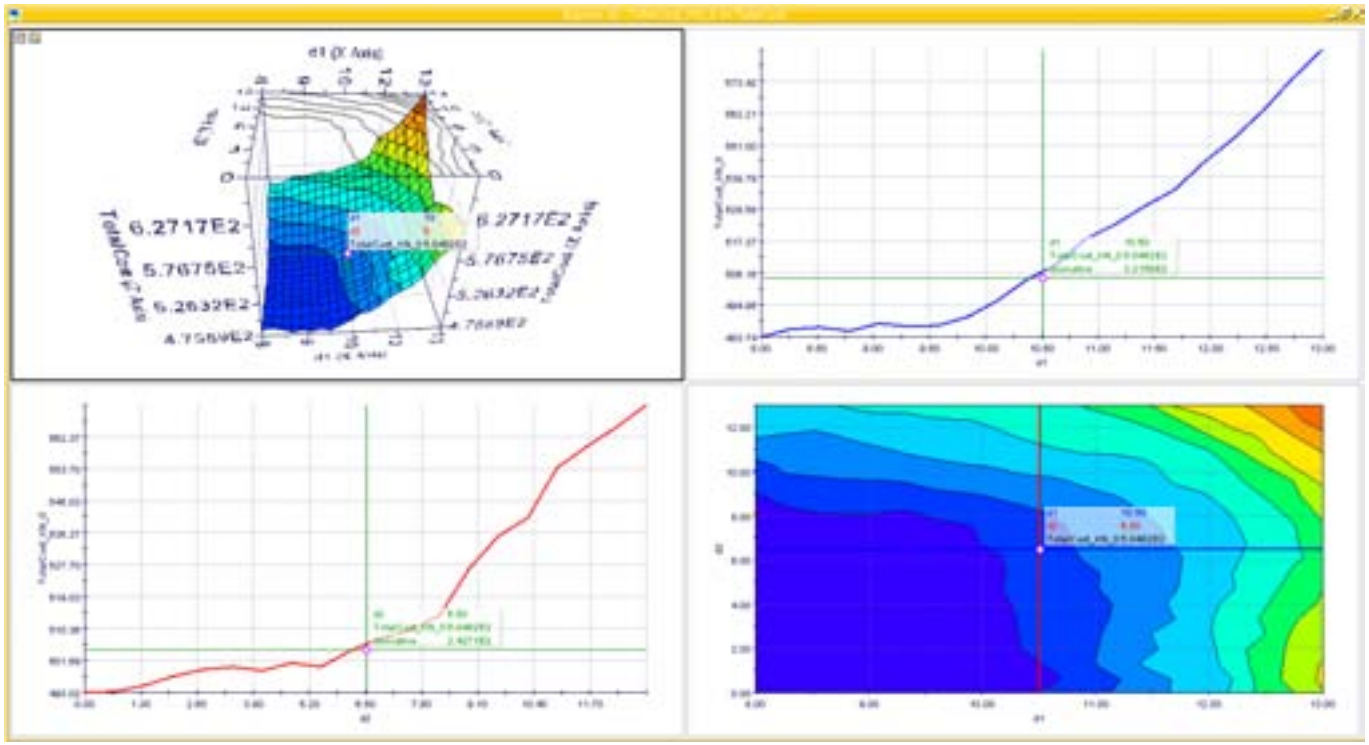
The MCDM tool



- The Multi Criteria Decision Making tool provided in modeFRONTIER assists the Decision Maker in finding the best solution from among a set of reasonable alternatives
- It allows the correct grouping of outputs into single utility function
- This utility function is coherent with the preferences expressed by the user through pairwise comparison of solutions or direct specification of attributes importance.

The Response Surface Methodology

- A collection of mathematical and statistical techniques useful for the modeling of problems
- RSM is used in engineering design to construct approximations of analysis codes
- Predictions made within the observed space of variable values are called **interpolations**. Predictions outside the observed values are called **extrapolations** and require caution
- Export formats: JAVA, C, FORTRAN



Thank you very much!

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