Front-End Module Design using MDO Approach

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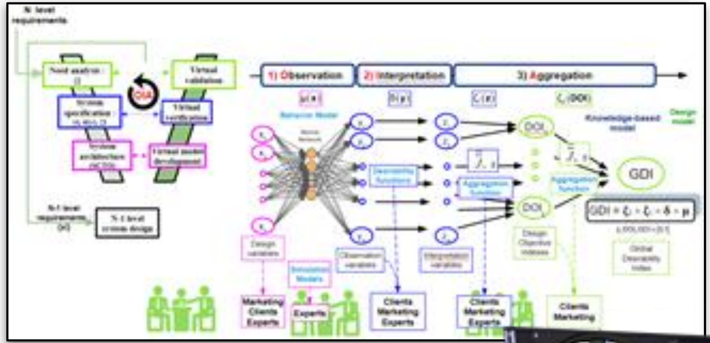
Jérémy Blandin, Dr. Kamel Azzouz, Dr. Pascal Menegazzi

SMART TECHNOLOGY FOR SMARTER MOBILITY



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Front End Module Design Introduction

What is a front end module ?

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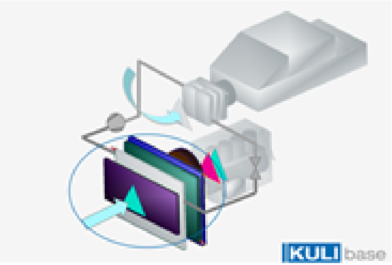
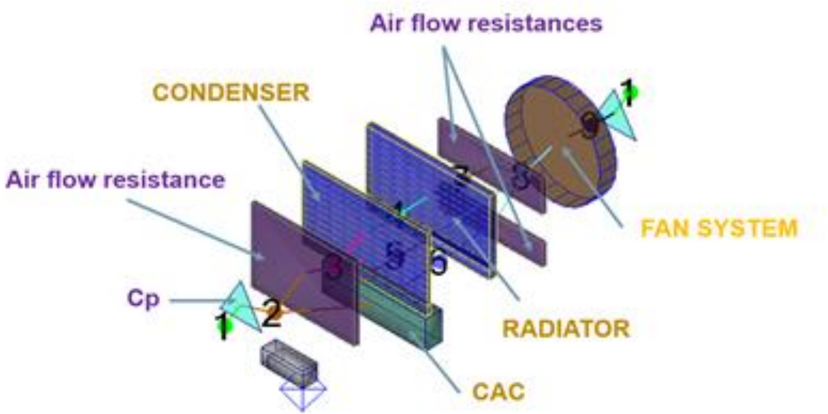


A front end module is necessary to **remove heat** from engine,cabin… to the ambient air.
All components **interact** with each other and with the vehicle to define local working conditions (temperature, pressure, air velocity)



Front End Module Example

3 main axis make up a cooling module (on air side):

1. **Heat Exchangers**
2. **Fan System**
3. **Environment (inlet grid…)**

Front End Module Design Overview & Target

1

DESIGN TARGET

Architectures [1 to 30]

Packaging Constraints

Heat Performance criteria for several boundary conditions [~10 to 20 Operating Points]

Acoustic criteria / Reliability

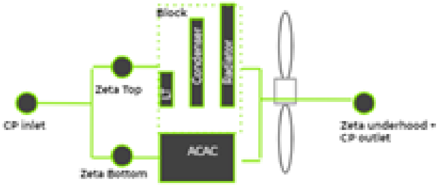
Cost

VALEO TARGET

Answer time

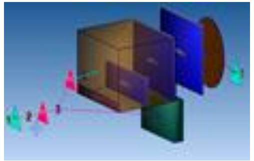
Cost

Re-use / Diversity limitation



+ **TOOLS & METHODOLOGY**

Selection & Optimization of each component




Simulation *Test*

ANSWER

Acceptable Front End Module Solutions but not **Optimal**

Project Objective: change from Acceptable to **Optimal** solution

Front end module design current Methodology

1

Initialization → Axis 1: Heat Exchanger → Axis 2 : Fan System → Axis 3 : Environment → Final Check

Numerical model creation with fixed assumption for all architectures

Heat Exchangers Selection
With fixed assumption on :
Axis 2 : Fan system (taken from a previous project)
Axis 3 : environment (assumption given as input)

Fan System Optimization
With heat exchangers defined in previous step

Environment assumption update
due to Axis 1 and Axis 2 modification

Check that target are reached.
If not Additional iteration

Optimization is a <u>sequential process & iterative</u>

Front end module design current Methodology

Conclusion on current process

1

- **Sequential process :**
  - *Not a global optimal approach*
  - *Acceptable solutions are found with difficult consideration of all criteria together(Reuse, variant, cost, etc.)*

Objective :
Implement an MDO Algorithm coupled with a Genetic Algorithm to go from Long Sequential Approach to Fast Global Approach

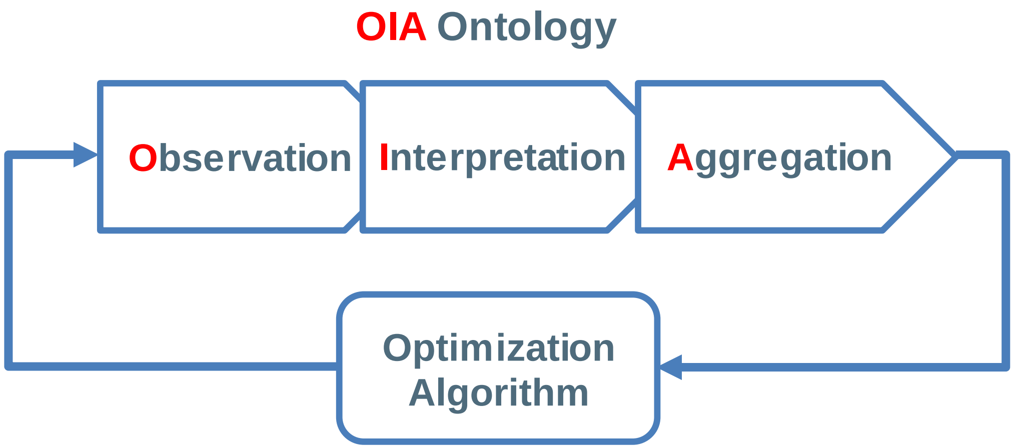
02

MDO Methodology Introduction

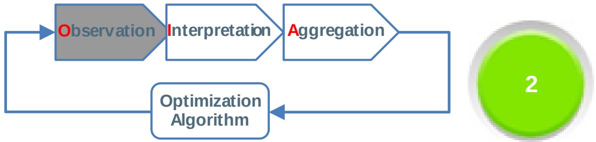
MDO (Multi-Disciplinary Optimization) methodology

2

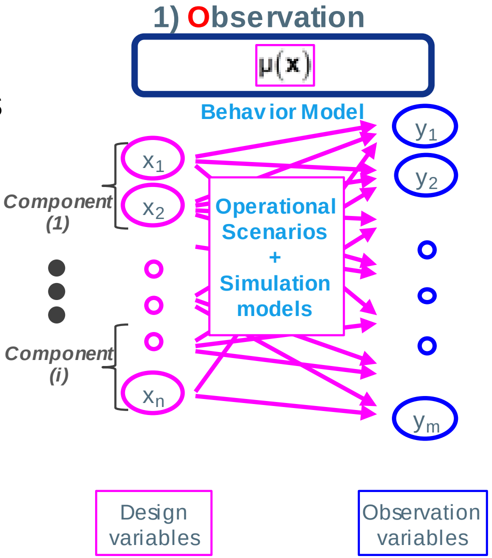
- Facilitate the **decision-making** in Multi-Disciplinary problem : optimization of several criterion simultaneously using a GLOBAL criterion
- Implicate the right **personnel** in order to :
  - Determine the design variables, scenarios and objectives, etc.
  - Adapt the way to trade-off.



MDO Methodology Introduction : OIA : Observation



(X) : Exchangers
+ Fan



(Y) Targets:
Temperature
Pressure drop
Cost
Packaging,
NVH, ...

(X) +

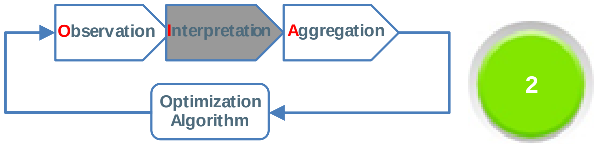
Scenarios

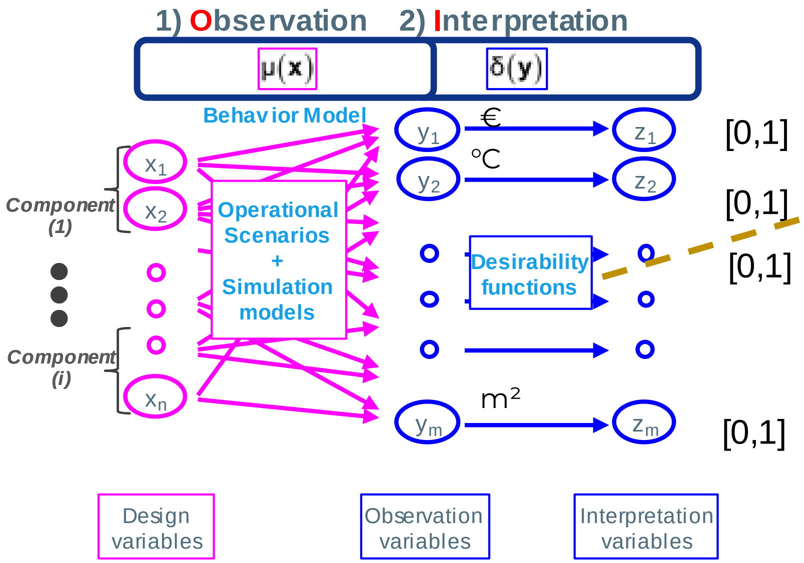
Operating Point #	1
	☑ Operating Point active
Comment	B35 2. Gang
Vehicle speed [km/h]	35
Fan speed [1/min]	3000
Ambient temperature [degC]	25
Ambient pressure [hPa]	1013
Engine speed [1/min]	2349,61901
Ambient humidity [%]	0

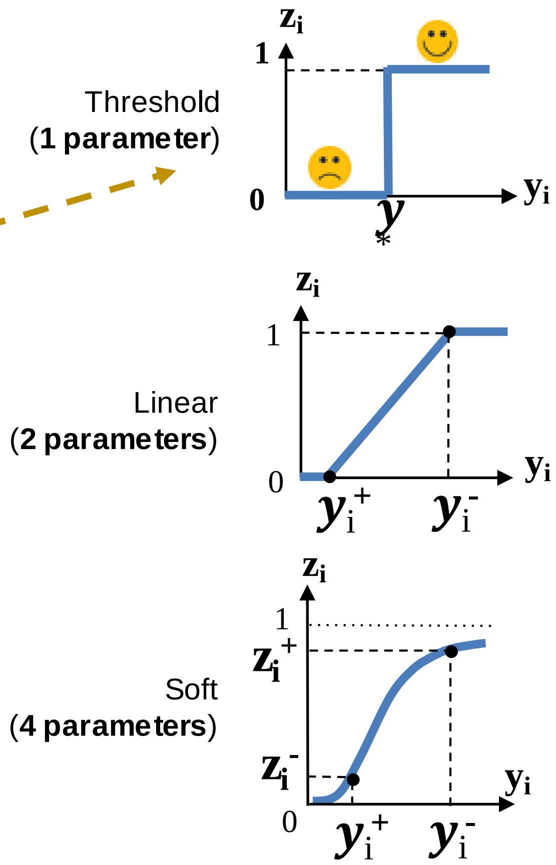
Simulation model

+	-	Select...	Run Simulations	Simulations Finished!
#		KULI Comp	Component Sensor	Unit
1		1.RAD	EntryTempIM	°C
2		1.CAC	ExitTempIM	°C

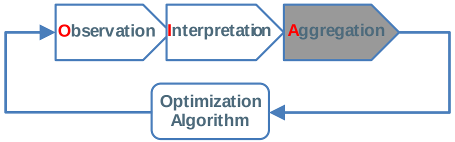
MDO Methodology Introduction : OIA : Interpretation







MDO Methodology Introduction : OIA : Aggregation



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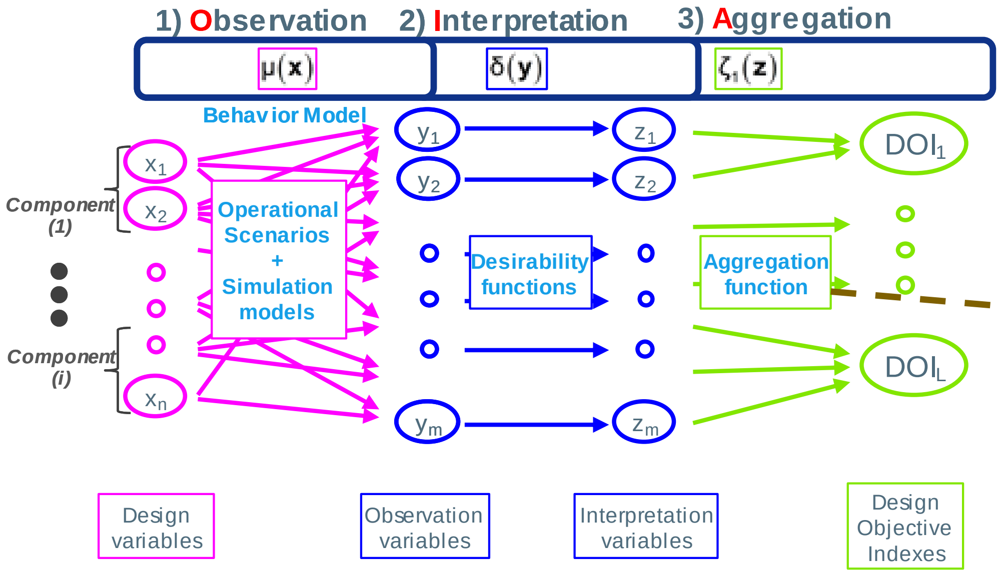
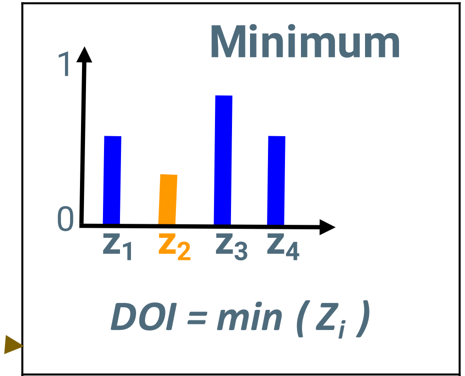
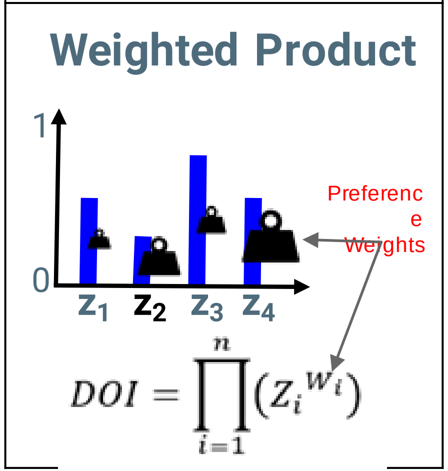
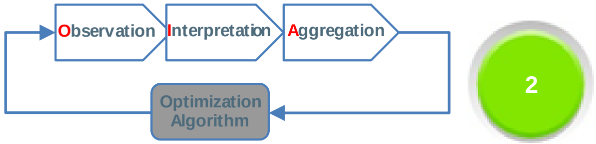
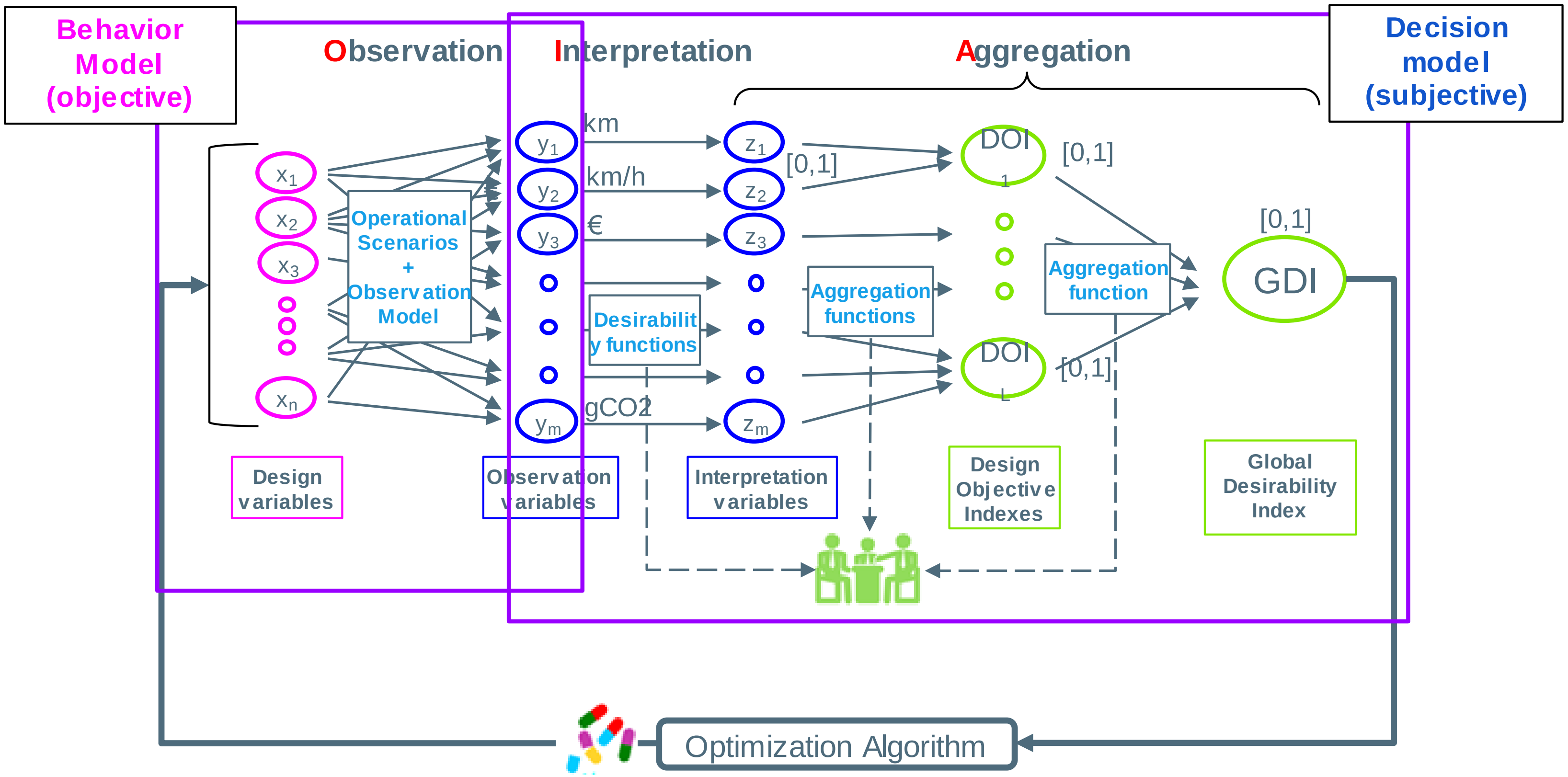






MDO Methodology Introduction : OIA : Optimization Algorithm

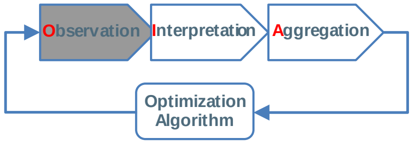




03

POC : Application to FEM Design

POC : Application to Front End Module Design : Observation model



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Observation Model

Inputs

- **Heat Exchanger (i)**
- **Charged Air Cooler (j)**
- **Fan (k)**
- **Position (z)**

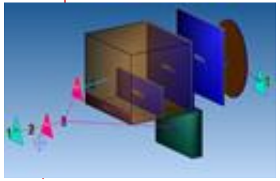
Excel : architecture and operation points.

Run Kuli for calculation

Receive Performance data

KULI

Kuli



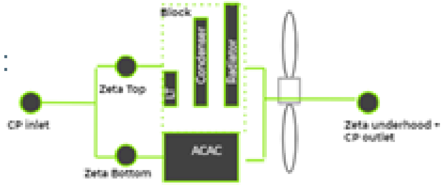
Outputs

- **Performance :** Temperature, Pressure drop
- **Packaging**
- **Cost**

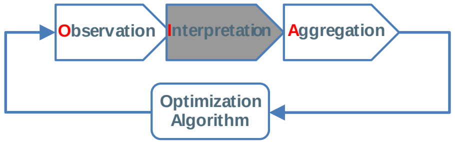
Components	1.RAD	Cost [€]	1.CAC	Cost [€]	1.nFan	Cost [€]
Lists	rad1_1p.kuliRad	xx	acac_100maxs_5	xx	fan1.kuliRPMFa	xx
	rad2_1p.kuliRad	xx	acac_100maxs_5	xx	fan2.kuliRPMFa	xx
	rad3_1p.kuliRad	xx			fan3.kuliRPMFa	xx
	rad4_1p.kuliRad	xx			fan4.kuliRPMFa	xx
	rad5_1p.kuliRad	xx				
	rad6_1p.kuliRad	xx				
	rad7_1p.kuliRad	xx				
	rad8_1p.kuliRad	xx				
	rad9_1p.kuliRad	xx				
	rad10_1p.kuliRad	xx				

Components database in Excel

Example of architecture :



POC : Application to Front End Module Design
Interpretation model



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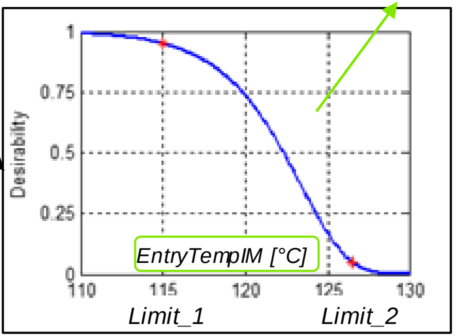
		Row	A: Targets	B: Limit_1	C: Limit_2	D: Function Name
		1	Targets	Limit_1	Limit_2	Function Name
Scenario 1	EntryTempIM 1	2	115,00	115,00	126,50	4
	ExitTempIM 1	3	65,00	65,00	71,50	4
Scenario 2	EntryTempIM 2	4	115,00	115,00	126,50	4
	ExitTempIM 2	5	65,00	65,00	71,50	4
		6	105,00	105,00	115,50	4
		7	65,00	65,00	71,50	4
		8	105,00	105,00	115,50	4
		9	65,00	65,00	71,50	4
		10	115,00	115,00	126,50	4
.	.	11	65,00	65,00	71,50	4
.	.	12	115,00	115,00	126,50	4
.	.	13	65,00	65,00	71,50	4
		14	105,00	105,00	115,50	4
		15	65,00	65,00	71,50	4
		16	105,78	105,78	116,36	4
		17	65,00	65,00	71,50	4
		18	105,00	105,00	115,50	4
		19	65,00	65,00	71,50	4
	Cost	20	118,00	118,00	129,80	4
	Packaging	21	54,00	54,00	59,40	4

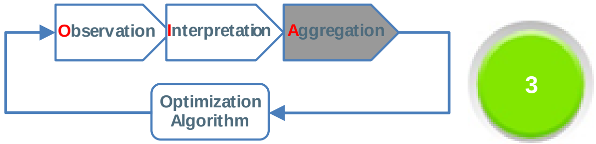
Function Name :

1. ***[0 or 1]***
2. ***Linear***
3. ***Harrington***
4. ***Sigmoid***

Function parameters

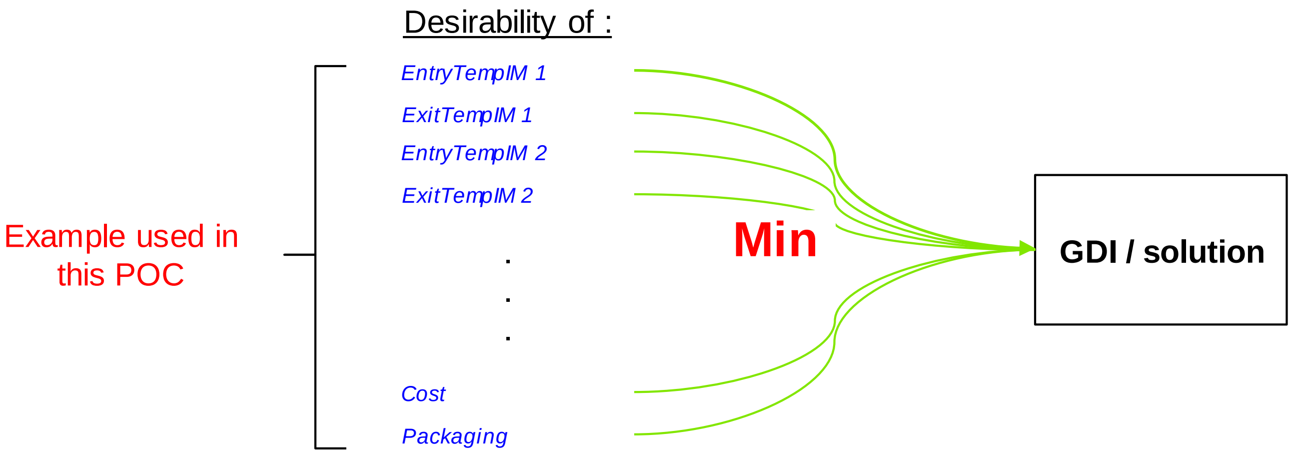


POC : Application to Front End Module Design
Aggregation model : GDI calculation

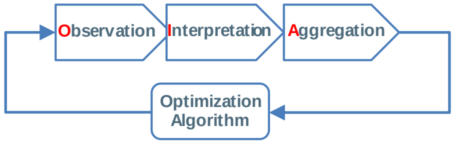


Two options to calculate the GDI :

1. Weighted product : ranking of objectives to find the weights (W_i)
2. **Use Max-of-Min : No need for weights**



POC : Application to Front End Module Design : Optimization method for FEM



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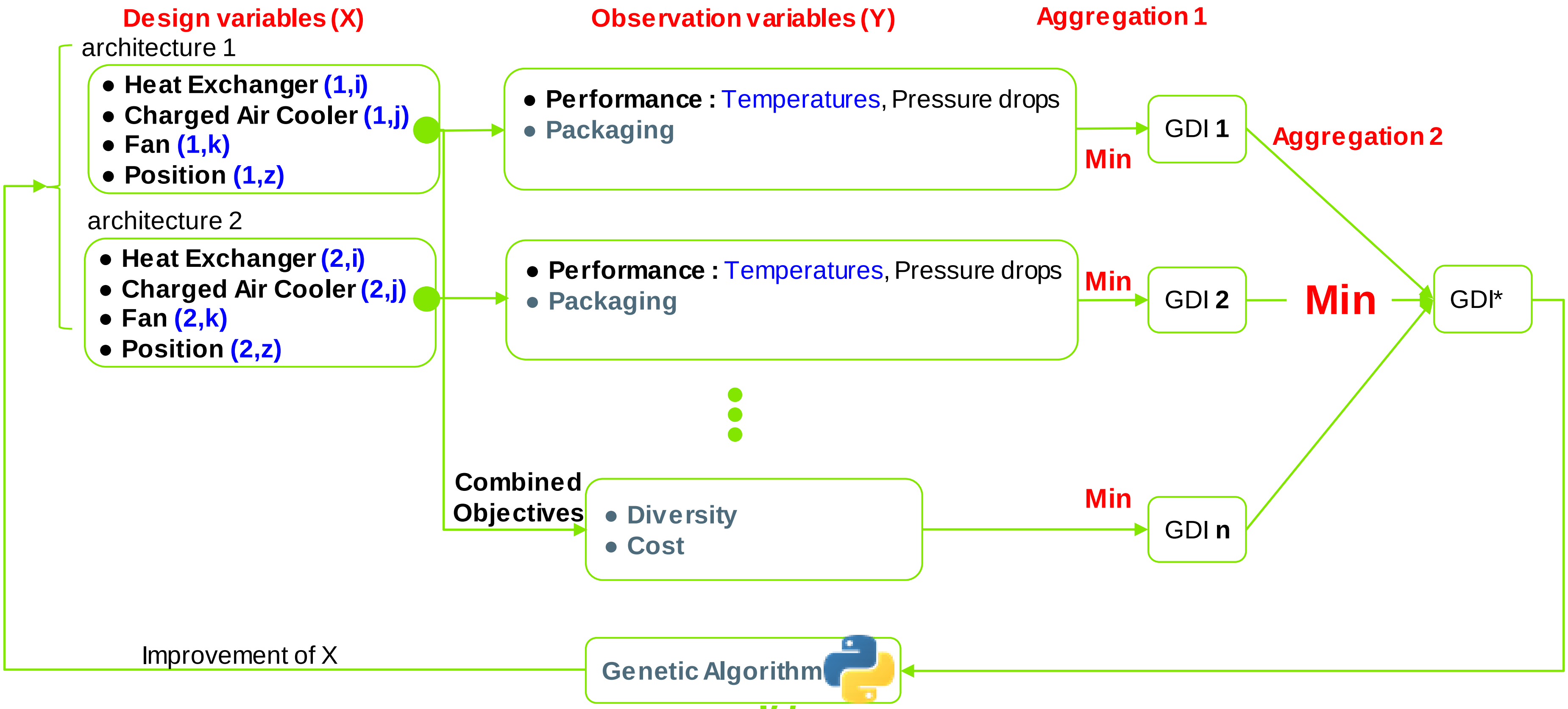

04

Synthesis of POC Results

POC Results

4

Use Case

- 2 Architectures
- 10 Scenarios
- 2 Local Target (temperature coolant & charged air)
- 2 Global Target (cost and diversity)

Design Variables

- Radiators (23 ref.)
- Charged Air Cooler (2 ref.)
- Fan (4 ref.)

33 856

Possible solutions

5 hours*
using laptop

149 Solutions
selected & evaluated

Huge potential to evaluate solutions and find the **optimal** solution in short time

POC Synthesis

- Organization of the problem :
  - Definition of design variables and criteria (objectives)
  - Ranking of criteria (Importance)
  - Implication of different actors (expert, marketing, customer…)
- A global optimization is possible:
  - Coupling of all subcomponents (Fan, exchangers, …) for one architecture in order to optimize the defined objectives
  - Coupling of all architectures in order to maximize the re-use of old components and minimize the diversity of components
- The optimization time is highly reduced comparing to the current methodology
- But difficult to evaluate accuracy when optimization modify air side architecture

Thanks for your attention

Contact :

jeremy.blandin@valeo.com

SMART TECHNOLOGY
FOR SMARTER CARS

Excel GUI developed during POC
Model & Calibration

Excel GUI developed during POC Simulation