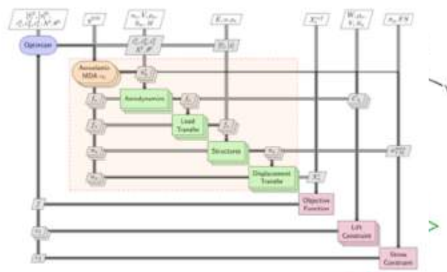
MDO in Academia: From classrooms to research

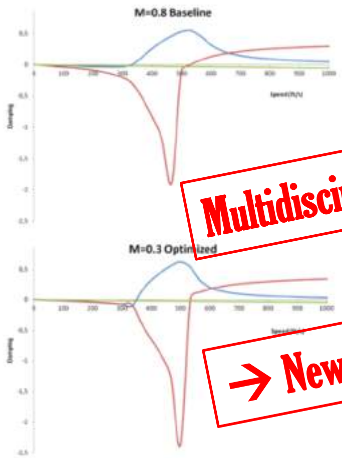
And vice versa

Nathalie Bartoli, Thierry Lefebvre, Joseph Morlier

Who am I ?

- 4 PhDs, 1 postdoc, 1 research assistant, 4 MsCs



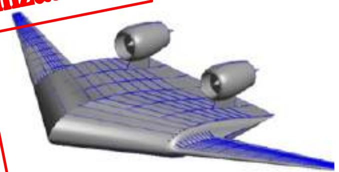


Multidisciplinary Design Optimization

→ New Aircraft Concept

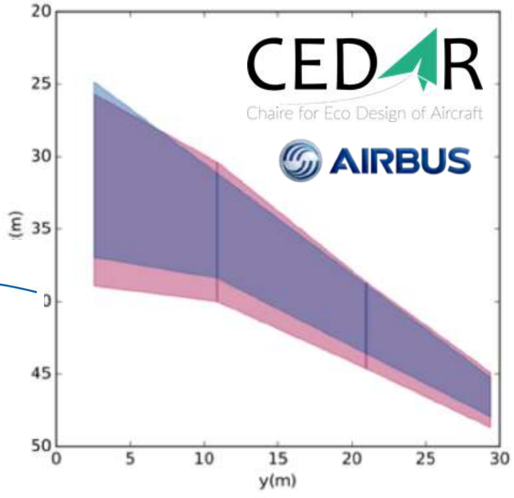
AEROSPACE ENGINEERING
UNIVERSITY of MICHIGAN

ONERA
THE FRENCH AEROSPACE LAB

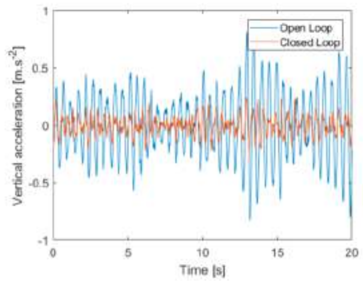


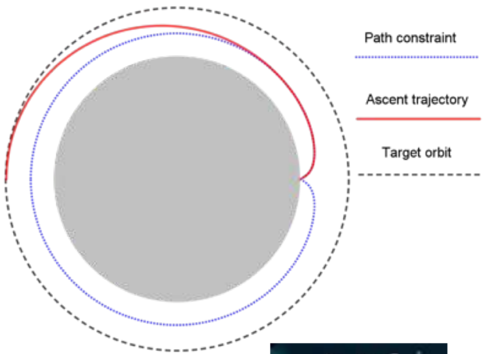
CEDAR
Chaire for Eco Design of Aircraft

AIRBUS

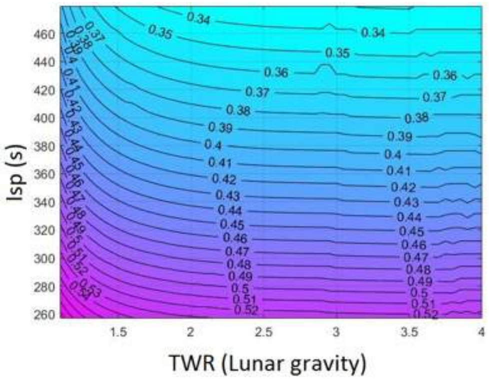


Optimized planform (red) and baseline (blue).





SAC LAB



New disciplines ←trajectory or control →

minimize $f(x) = w_1 k_h + w_2 \bar{h}_{max}(t, V_f^{CL})$

with $x = (k_h, Q, R)$[4]

subject to
$$\begin{cases} V_f^{CL} > 1.2 V_{f\,x_0}^{OL} \\ \left|\beta_{max}(t, V_f^{CL})\right| < \beta_{ref} \\ f_{max}^{i} < 3 f_{max\,x_0}^{i} \end{cases}$$

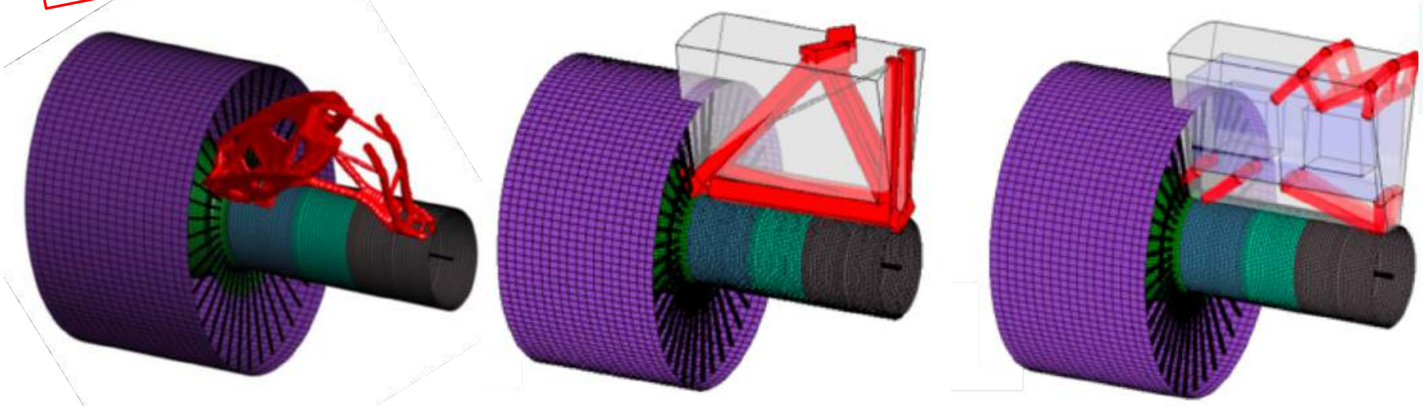
where
V_f^{XL} is the open loop (OL) or closed loop (CL) flutter velocity at the current iteration
β_{ref} is the maximum control surface deflection
f_{max}^{i} is the maximum frequency of mode i
$V_{f\,x_0}^{OL}$ is the open-loop flutter velocity at the starting point
Q, R are the LQR weight matrix to compute K

AIRBUS

Structural Optimization can really change the Design, Isn't it?

Multidisciplinary Design Optimization

Topology Optimization



joseph morlier

Professor in Structural and Multidisciplinary Design Optimization, ... any i...

5 j

Very proud of this work thanks to Simone Coniglio !!!

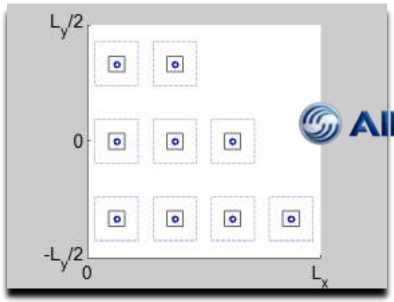
Geometric Feature Based Topopt

#TOPOPT #ISAE #ICA #SUPAERO

Archives of Computational Methods in Engineering

Generalized Geometry Projection: A Unified Approach for Geometric Feature Based Topology Optimization

link.springer.com



AIRBUS

AIRBUS

Isogeometric Optimization

http://www.institut-clement-ader.org/pageperso.php?id=jmorlier

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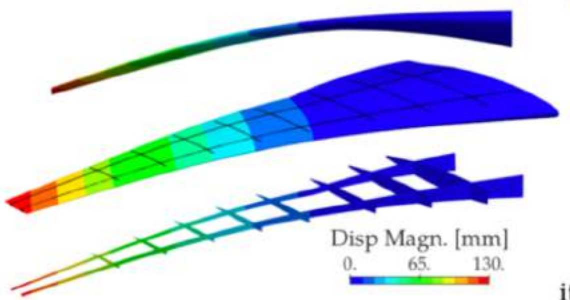
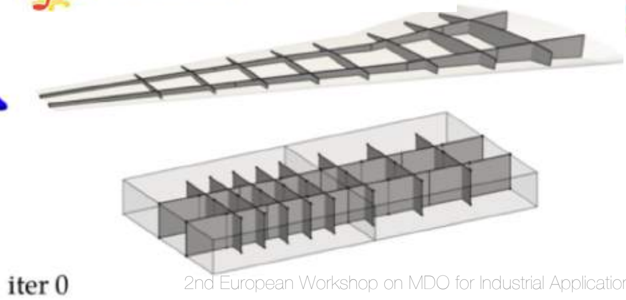
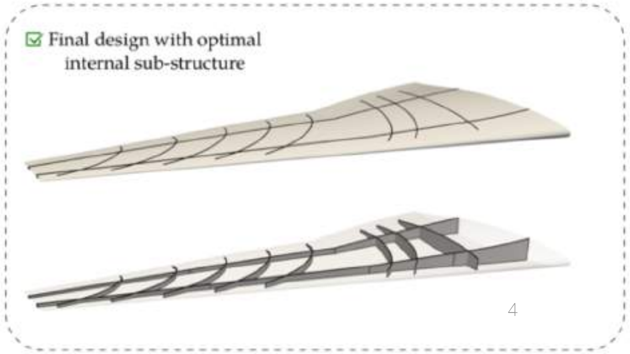
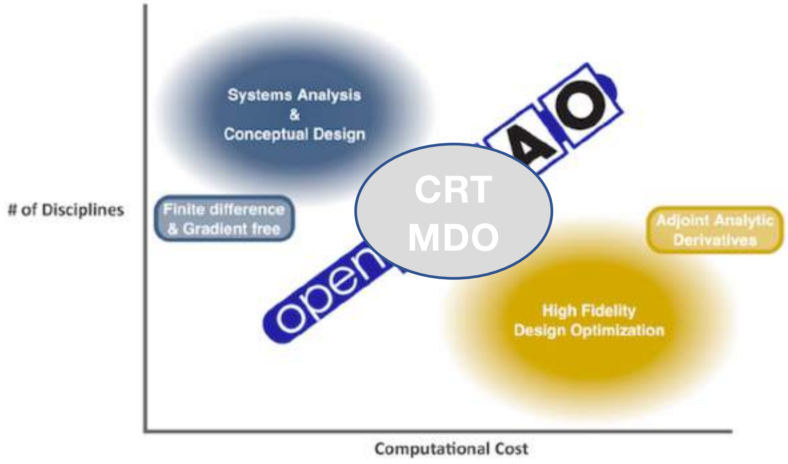
LaMCoS Unité Mixte de Recherche 5259







Common Research Team (ONERA+SUPAERO+…ENAC) :



CRT 10+ researchers

Opensource tools

facebookexperimental / **FBHALE**

Watch 11

Code | Issues 2 | Pull requests 0 | Actions | Projects 0 | Wiki | Security | Insig

FBHALE provides a conceptual multidisciplinary design framework for high altitude long endurance (HALE)

Structural and Multidisciplinary Optimization
https://doi.org/10.1007/s00158-019-02298-4

EDITORIAL

Check for updates

Replication of results

Raphael T. Haftka[1] • Ming Zhou[2] • Nestor V. Queipo[3]

Received: 28 January 2019 / Revised: 18 April 2019 / Accepted: 30 April 2019
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nasa / **NASTRAN-95**

usuaero / **panairwrapper**

FLOW Lab Website

HTML 1 0 0 0 Updated 3 days ago

multidisciplinary-optimization whatsopt

Outlines for today

#EfficientGlobalOptimization
#Multifidelity
#Typeofdesignvariables
#Studentskills

1. Starting point X_0
2. Examples
3. Synergy with SMT
4. Classrooms and add-ons
5. Conclusion and future works

Outlines for today

1. Starting point X_0
2. Examples
3. Synergy with SMT
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A long story short

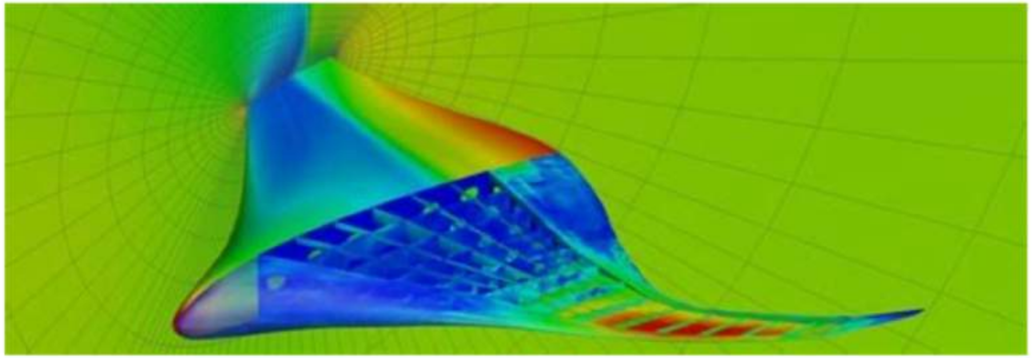
- A French ANR project over the period 2005-2009 (OMD-RNTL titled as, Multi-Disciplinary Optimization coordinated by Rodolphe Leriche of the Engineering school "Mines de St Etienne") has allowed to federate the French researchers in computational mechanics and design optimization. (Most of our works done in SCILAB… the french free clone of MATLAB)

→…OpenMDAO appeared in 2010

- In 2015 ISAE-SUPAERO hosted Prof. Martins* as a visiting professor via an European grant (H2020-MSCA-IF-2014_ST)
- January 2015, MDA-MDO project launched at IRT Saint-Exupéry (GEMS framework)
- June 2015, The European H2020 project AGILE has contributed to the formalization of the MDO processes and the development of numerous opensource tools for aircraft design.

- In 2017, the MDOlab released the SMT python toolbox conjointly developed by NASA, University of Michigan UoM, ONERA and ISAE-SUPAERO.

Popularization for our common research ONERA-SUPAERO



http://mdolab.engin.umich.edu

https://www.linkedin.com/pulse/optimization-mdo-connecting-people-joseph-morlier/

Optimization [MDO] for connecting people?

Publié le 14 février 2019 Modifier l'article | Voir les stats

joseph morlier
Professor in Structural and Multidisciplinary Design Optimization, ... any idea?
2 articles

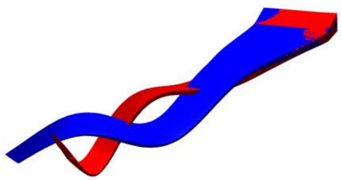
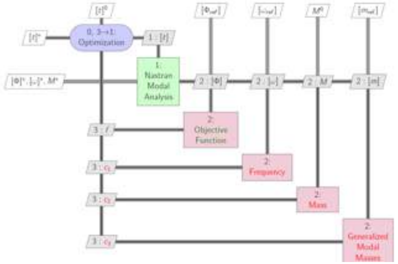
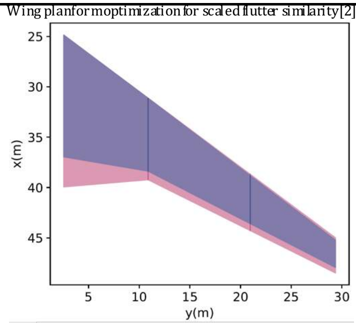
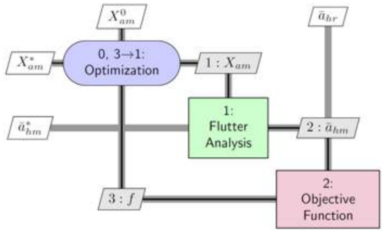
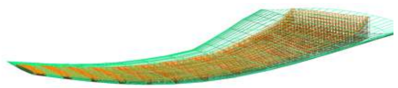
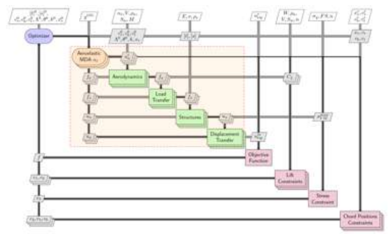
74 31 3 0

Outlines for today

1. Starting point X_0?
2. **Examples**
3. Synergy with SMT
4. Classrooms and add-ons
5. Conclusion and future works

PhD's projects

https://github.com/mid2SUPAERO/aerostructures

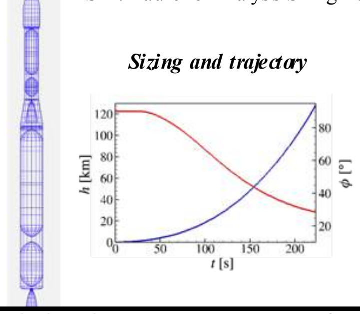
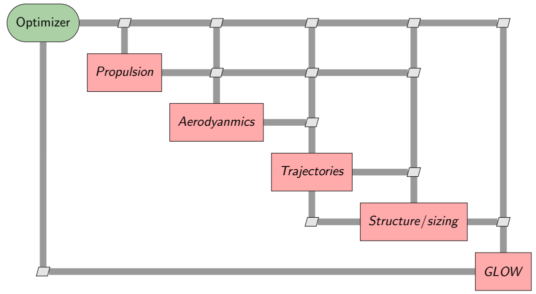
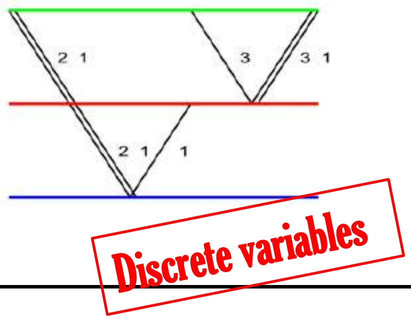
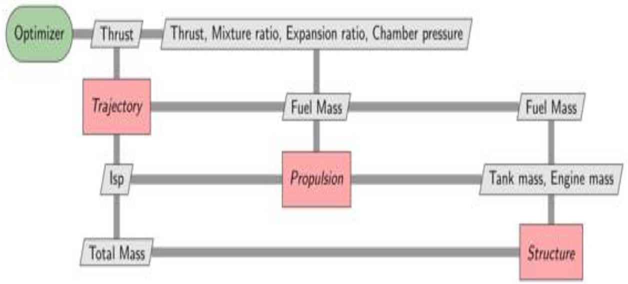
Problem	Model structure	Design variables	Objective	Constraints
Modal optimization for aeroelastic scaling [1] 		Thicknesses, stringer sections	Modal Assurance Criterion	Eigenfrequencies, mass
Wing planform optimization for scaled flutter similarity [2] 		Chord lengths, sweep angle	Norm of the difference between aerodynamic matrices	-
Multidisciplinary optimization for similar static aeroelasticity [3] 		Thicknesses, stringer sections, planform, root twist, thickness-to-chord ratio	Static wing deflection error	Lift, stress, longitudinal position of wing sections

Aeroelasticity
Flying Demonstrator

(OpenNastran, Panair, Adflow)

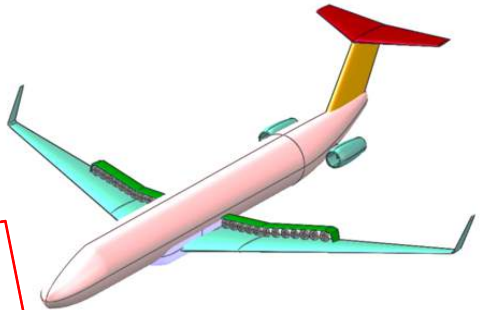
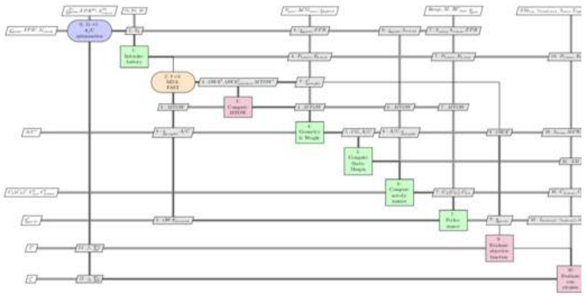
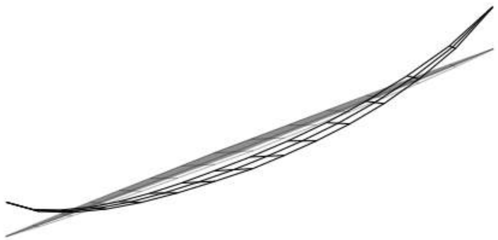
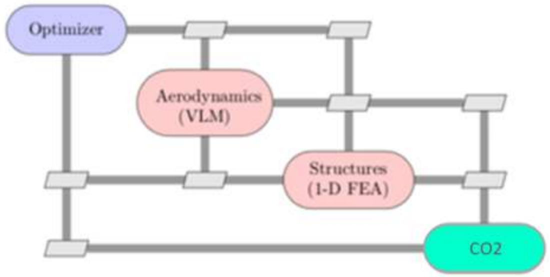
AEROSPACE ENGINEERING
UNIVERSITY of MICHIGAN

And more recently… for Space Application at SUPAERO

Problem	Model structure	Design variables	Objective	Constraints
LAST : Launcher Analysis Sizing Tool 		Chamber pressure, exit pressure, thrust to weight ratio, oxidizer to fuel ratio, inert mass fraction, trajectory control law	GLOW (Gross Lift-Off Weight)	Max loads, max heat fluxes, final altitude
Multidisciplinary Design Optimization of a Reusable Lunar Vehicle[2] 		Thrust, type of fuel, mixture ratio, expansion ratio	Average mass used per mission	Thrust to weight ratio >1 for landing and take off

PhD's projects

Aircraft and HALE preliminary design

Regional Electric AC [4a] or BWB [4b] conceptual design 		Thicknesses, twists, material, geometry	Mono or Multi bjective optimization	Available power, stress, flight
HALE ecodesign MDO 		Thicknesses, twists, material, geometry	CO2 footprint	Available power, stress, flight

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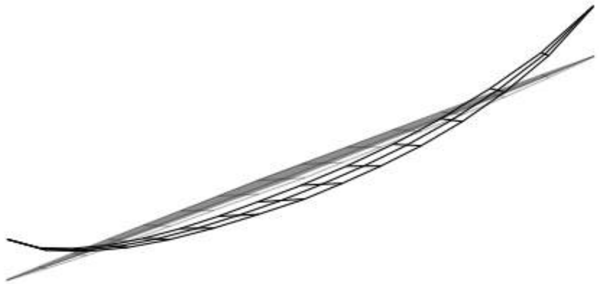
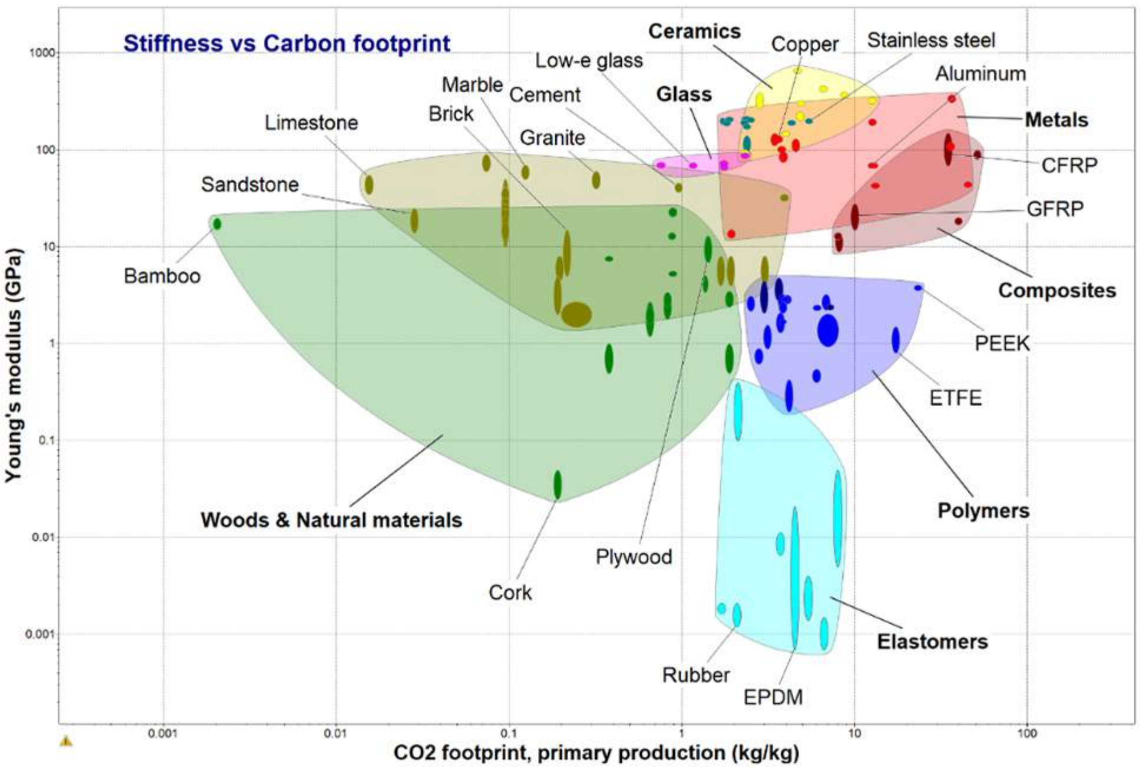
ECO Hale

https://www.openscience.fr/Maitriser-la-conception-des-drones-solaires-a-voilure-souple-vers-l-avenement

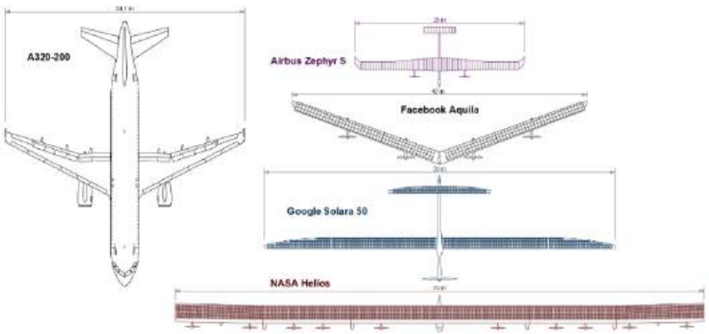
Derive OAS 2.0 to treat a HALE pseudo sattelite Design problem

HALE ecodesign MDO





Assets: Flexible, repositionable, permanent coverag
lower environnemental impact?



ECO MATERIAL SELECTION

Turn discrete problem of material selection into continuous inspired from SIMP

Zuo, W., & Saitou, K. (2016). Multi-material topology optimization using ordered SIMP interpolation. Structural and Multidisciplinary Optimization, 55(2), 477-491. doi:10.1007/s00158-016-1513-3

- Acces material properties through density (only one material design variable) :

  E(ρ) , G(ρ), σ_{yield}(ρ), CO2(ρ) (production CO2 footprint)

- Example for young modulus : Between two materials i and i+1,

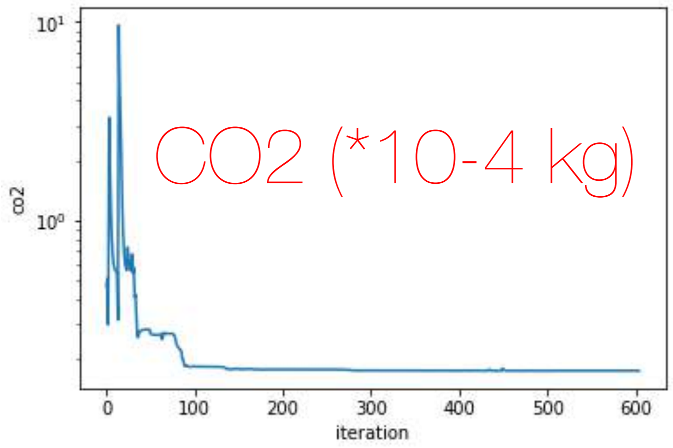
$$E_e(\rho_e) = A_E * \rho_e^p + B_E \quad \text{, with } A_E = \frac{E_i - E_{i+1}}{\rho_i^p - \rho_{i+1}^p} \text{ and } B_E = E_i - A_E * \rho_i^p$$

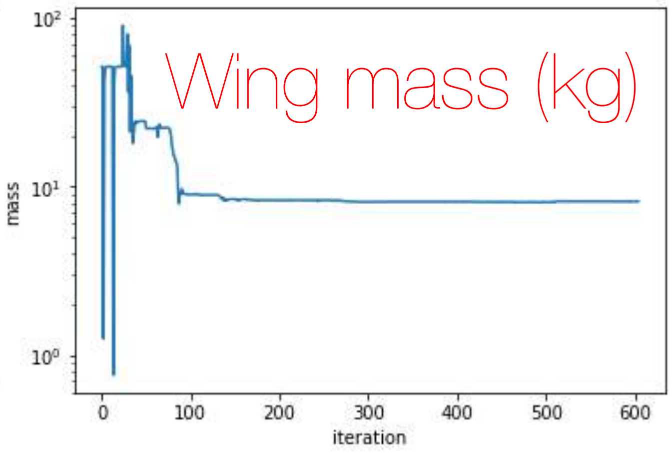
- Power p added during optimisation so that only real materials are optimal
- Inversed curvature for CO2 as smaller CO2 is more advantageous

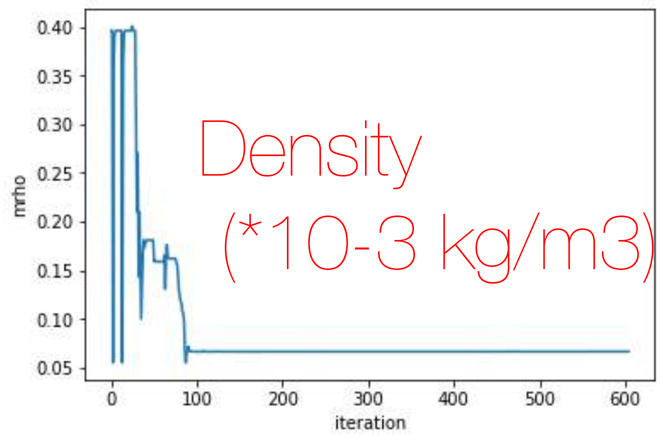
Our design variables

Variable	Lb	Ub	X0 **(multistart)**	unit
Skin thickness	0,0001	0,1	0,01-0,001	m
Spar thickness	0,0001	0,1	0,01-0,001	m
Wing span	1	1000	50	m
Wing chord	1	500	2	m
Wing taper	0,01	0,99	0,1	-
Wing thickness over chord ratio	0,01	0,20	0,1	-
Twist	-15	15	5	°
Density	50	8200	50-8200	Kg/m3

RESULTS





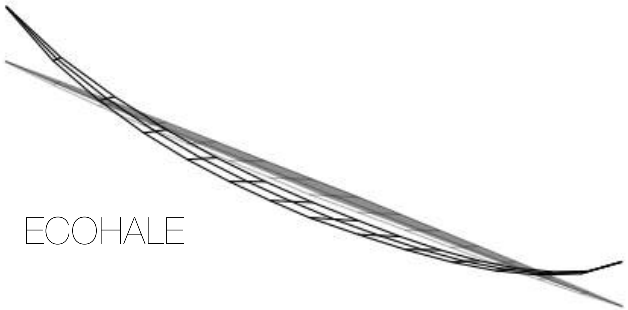


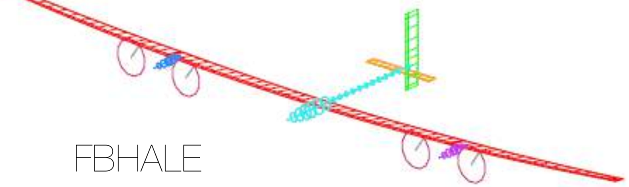
- The final material is a sandwich panel (UD CFRP – expanded PS foam – UD CFRP)
- The optimal material in terms of CO2 is very close to the optimal material in terms of weight, because battery is the most impacting on CO2

ECODESIGN IN THE MDO LOOP

- HALE could be a smart alternative to satellites (~~launching~~) => important to make them as clean as possible.
- Our method of material selection can be adapted to any aerostructure. Still working on multimaterials

Variable	ECO HALE **OpenAeroStruct**	FBHALE
Span (m)	48	45
Chord (m)	1,04	1,6
Total mass (kg)	107	320
Battery+PV mass (kg + %total)	54(50%)	170 (53%)
Payload+avionics mass (kg + %total)	20,5 (19%)	28 (9%)
Wing Structure mass (kg + %total)	30 (28%)	67 (21%)


ECOHALE


FBHALE

Colas, D., Roberts, N. H., & Suryakumar, V. S. (2018). HALE Multidisciplinary Design Optimization Part II: Solar-Powered Flying-Wing Aircraft. In 2018 Aviation Technology, Integration, and Operations Conference (p. 3029).

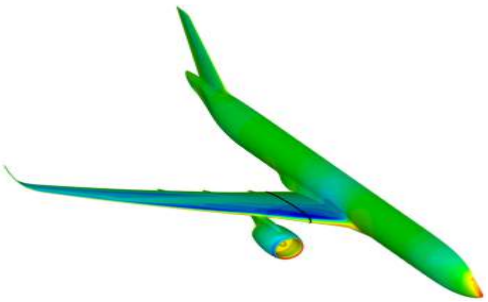
Outlines for today

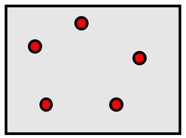
1. Starting point X_0
2. Examples

3. Synergy with SMT

4. Courses and add-ons
5. Conclusion and future works

Surrogate modeling Recipes

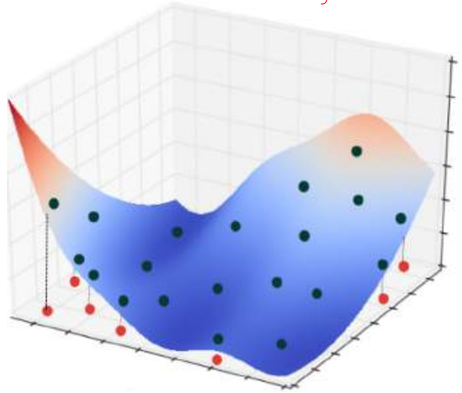


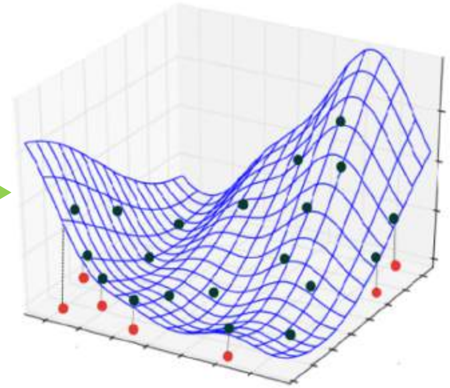


DOE

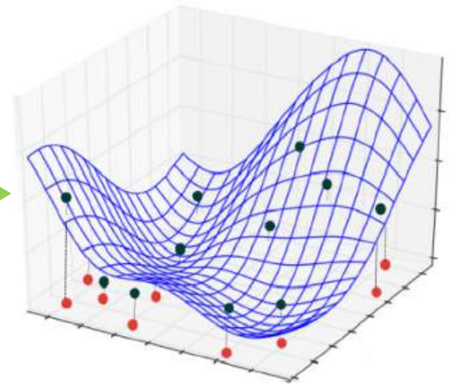
True Function Evaluation

This is costly!





Interpolant model



Regression model

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(\hat{y}_i - y_i)^2$$

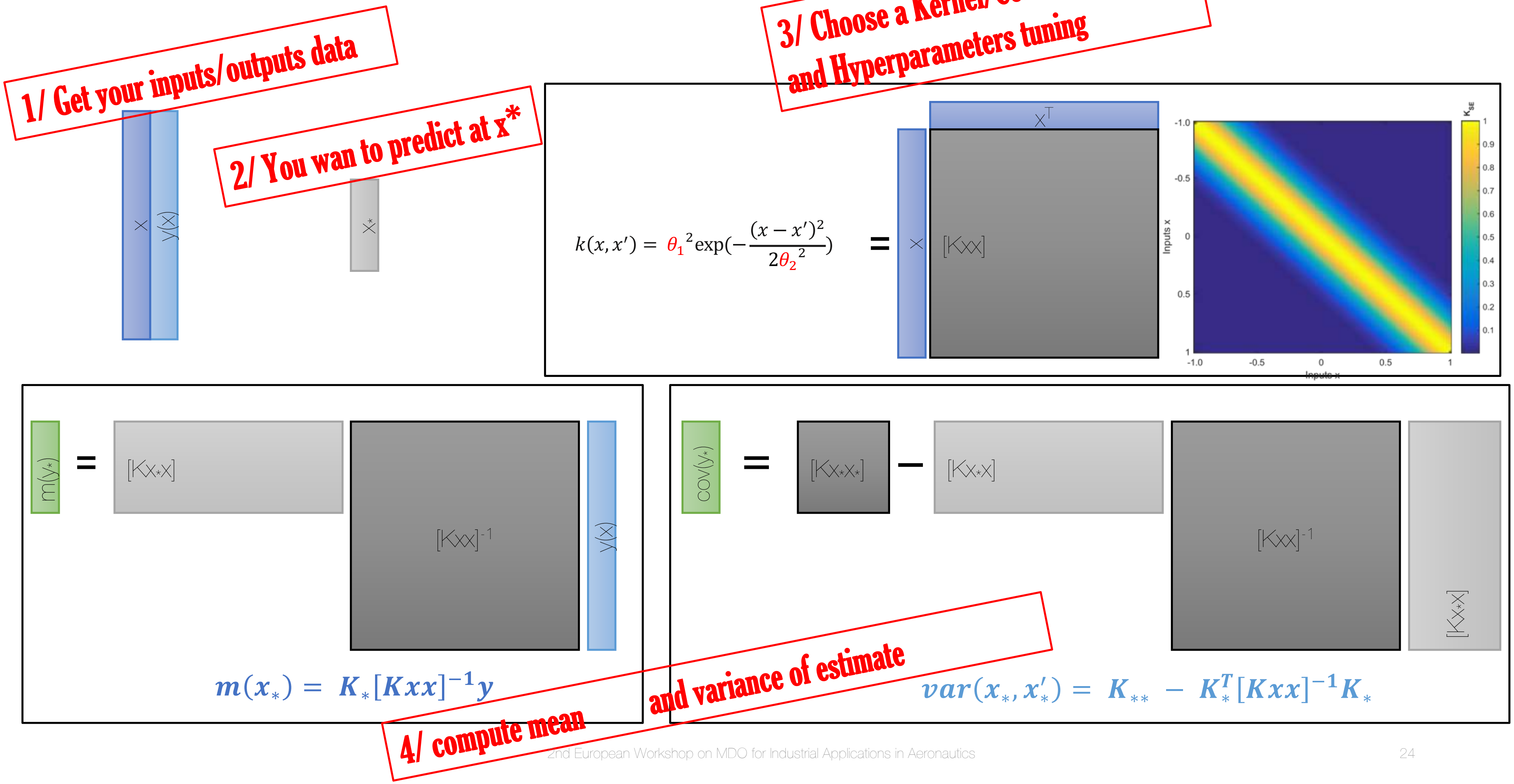
$$LOF = \frac{MSE}{Var(y)}$$

n is the number of samples

$\hat{y}$ is the predictions of the n samples

y is the true outputs of the n samples

Matrix view of Gaussian Process



«Costly code» reduction with GP

But also can help to optimize…

HOW?

joseph morlier

Professor in Structural and Multidisciplinary Design Optimization, ... any i...

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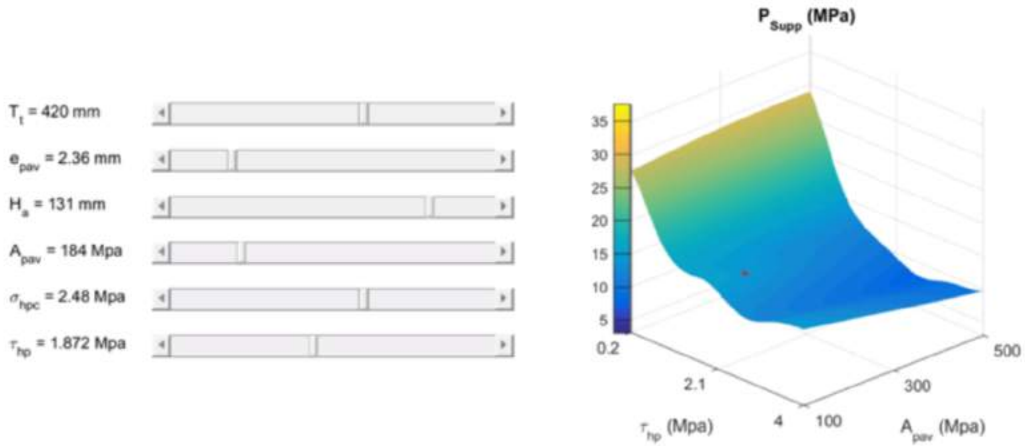
#ML

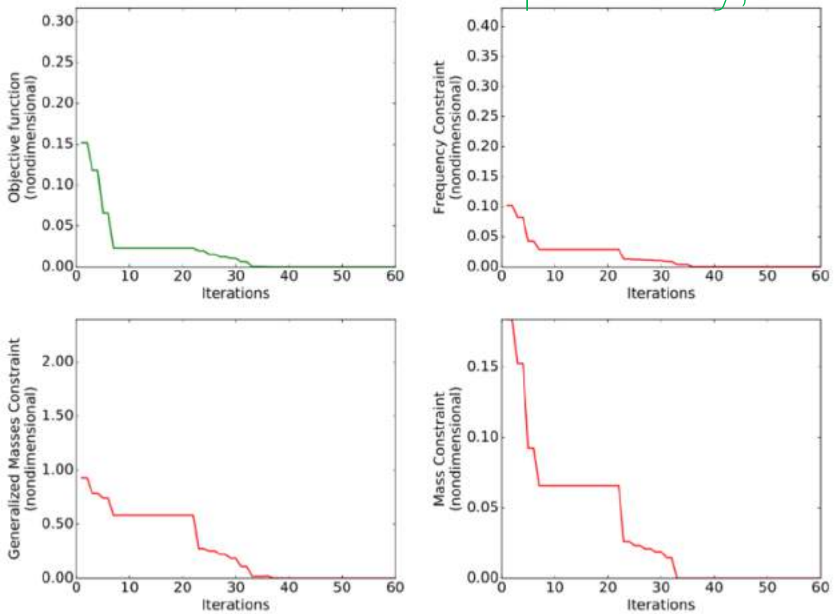
Have a look to one of our 2018 paper, where Machine Learning or Surrogate modelling technics help to understand Complex mechanical behaviour (impact on sandwich shield)

https://lnkd.in/dr_WSqA

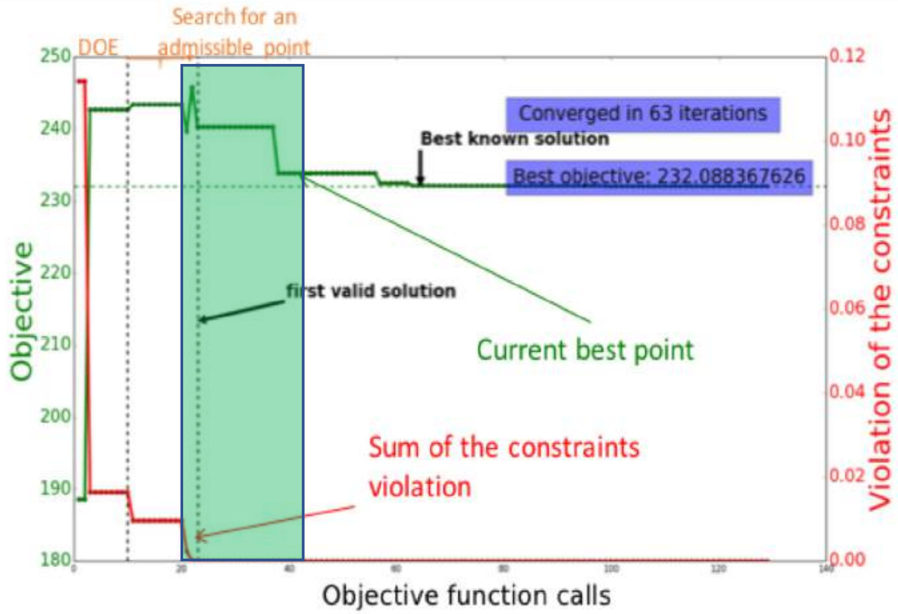


New graphs

Gradient based Optimality, Feasibility



SBO Exploration, Exploitation

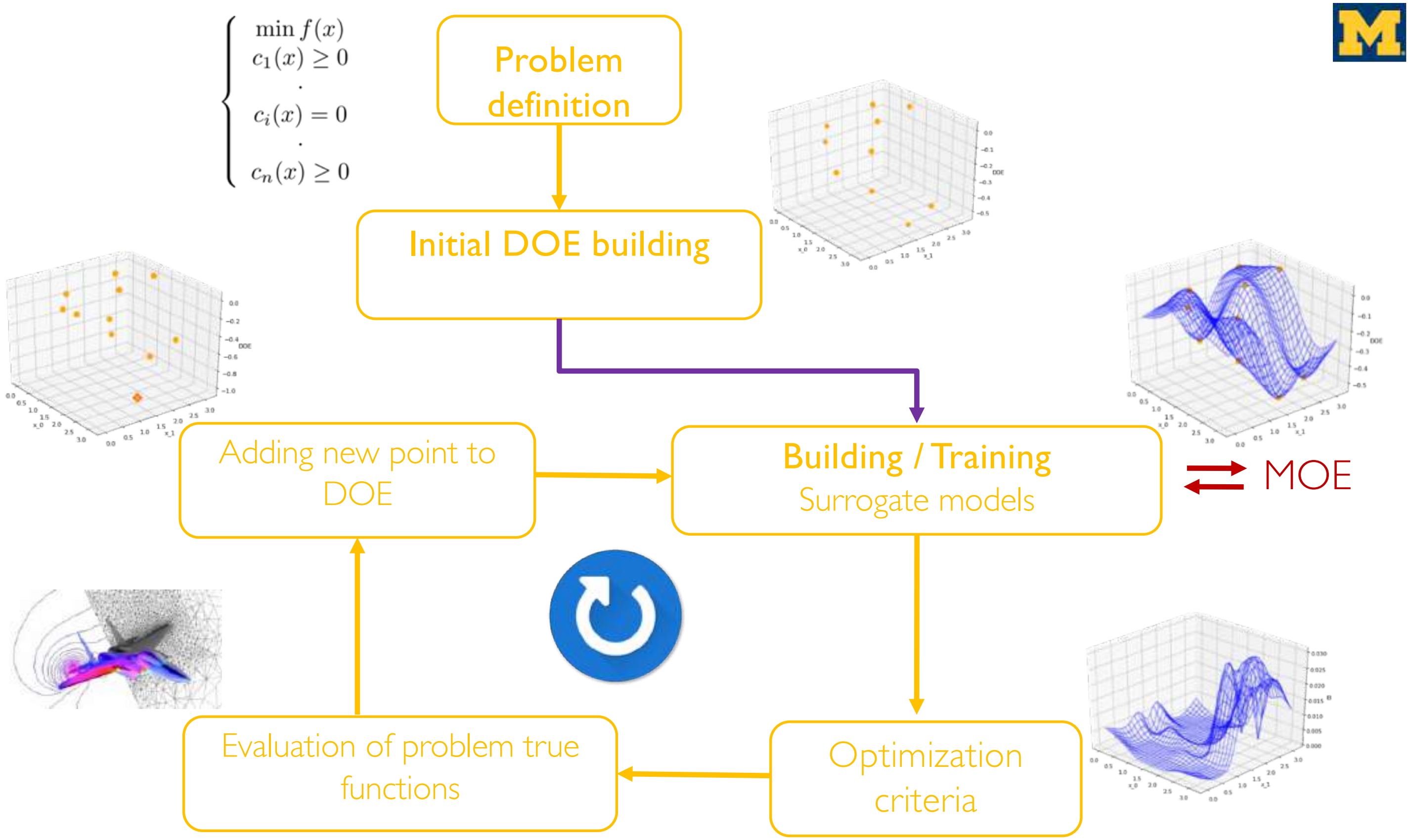


Stopping criteria: tolfun, tolx, maxiter

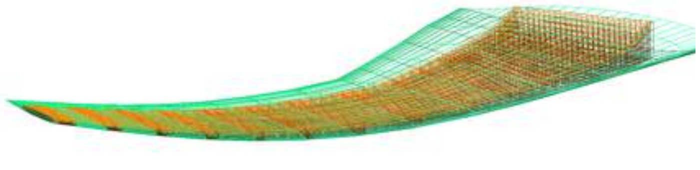
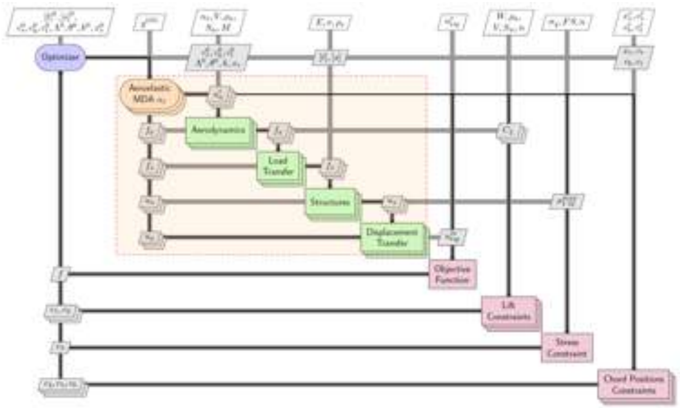
Stopping criteria: Max Budget (Function calls)

SEGOMOE algorithm

Bartoli, N., Lefebvre, T., Dubreuil, S., Olivanti, R., Priem, R., Bons, N, Martins, J. R. & Morlier, J. (2019). Adaptive modeling strategy for constrained global optimization with application to aerodynamic wing design. Aerospace Science and technology, 90, 85-1



Static Optimization (SEGOMOE)

Multidisciplinary optimization for similar static aeroelasticity [3]  	Thicknesses, stringer sections, planform, root twist, thickness-to-chord ratio	Static wing deflection error	Lift, stress, longitudinal position of wing sections

Problem

Objective Function

Wingtip displacement error minimiz

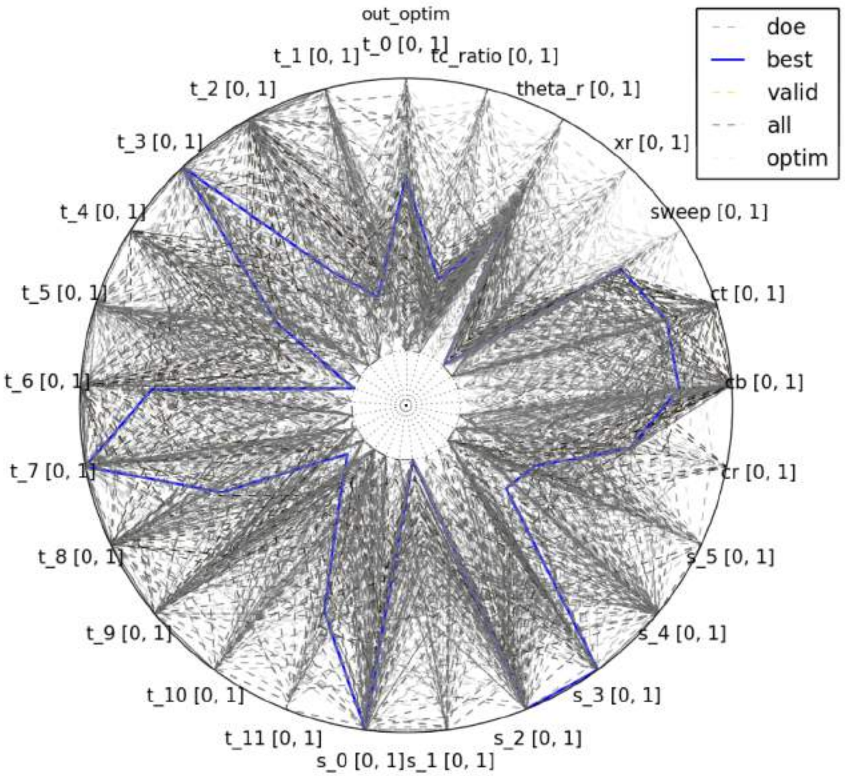
Design Variables

struct.
- Thicknesses vector
- Stringer section vector

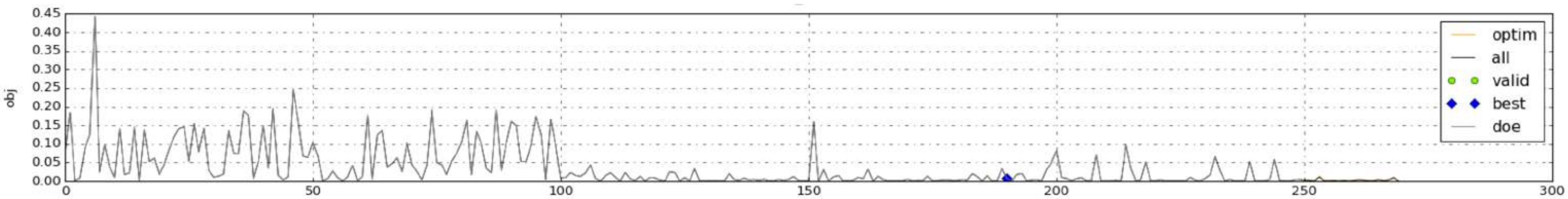
geom.
- Root chord
- Break chord
- Tip chord
- Sweep
- Wing mounting angle
- Root leading edge
- t/c scaling factor

Constraints

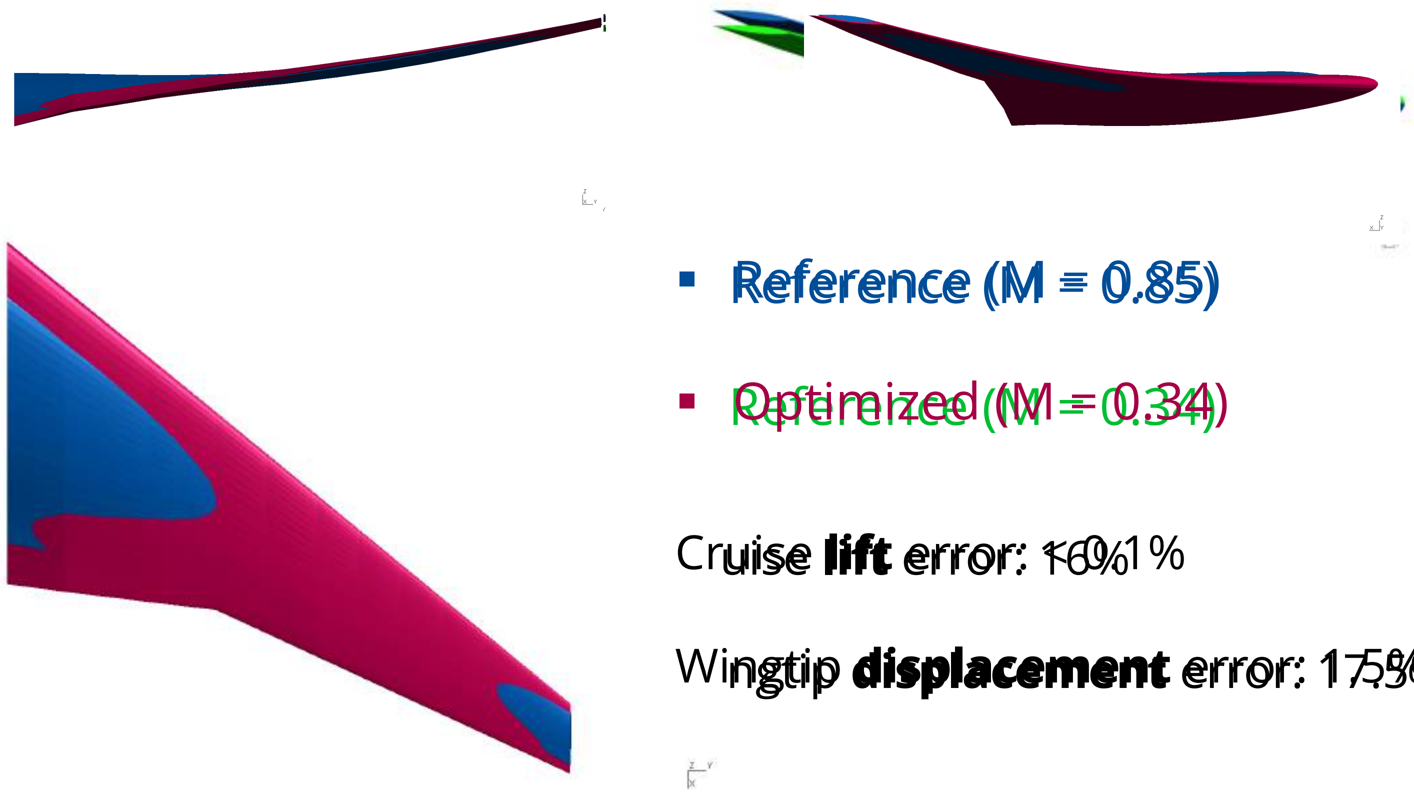
Lift constraints



better than COBYLA



RESULTS



- Reference (M = 0.85)
- Optimized (M = 0.34)
- Reference (M = 0.34)

Cruise **lift** error: <0.1%

Cruise **lift** error: 16%

Wingtip **displacement** error: 17.5%

Surrogate Model Toolbox: SMT https://github.com/SMTorg/SMT

AEROSPACE ENGINEERING
UNIVERSITY of MICHIGAN

NASA

isae SUPAERO

ONERA
THE FRENCH AEROSPACE LAB

Table of Contents

Next topic

Getting started

This Page

Show Source

Thanks to Mohamed Bouhlel

SMT: Surrogate Modeling Toolbox

The surrogate modeling toolbox (SMT) is an open-source Python package consisting of libraries of surrogate modeling methods (e.g., radial basis functions, kriging), sampling methods, and benchmarking problems. SMT is designed to make it easy for developers to implement new surrogate models in a well-tested and well-document platform, and for users to have a library of surrogate modeling methods with which to use and compare methods.

The code is available open-source on GitHub.

KPLS, RMTS, GEK

Cite us

To cite SMT: M. A. Bouhlel and J. T. Hwang and N. Bartoli and R. Lafage and J. Morlier and J. R. R. A. Martins. A Python surrogate modeling framework with derivatives. Advances in Engineering Software, 2019.

```
@article{SMT2019,
        Author = {Mohamed Amine Bouhlel and John T. Hwang and Nathalie Bartoli and Rémi Lafage
        Journal = {Advances in Engineering Software},
        Title = {A Python surrogate modeling framework with derivatives},
        pages = {102662},
        year = {2019},
        issn = {0965-9978},
        doi = {https://doi.org/10.1016/j.advengsoft.2019.03.005},
        Year = {2019}}
```

Focus on derivatives

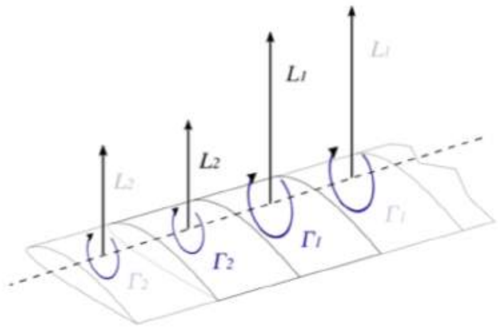
3 types of derivatives…

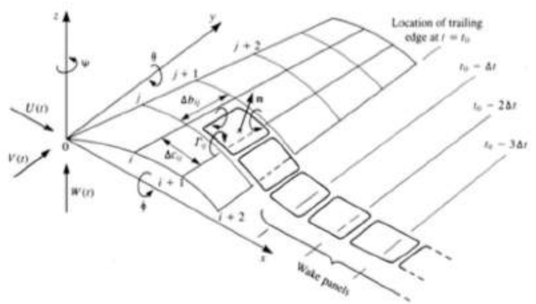
M.-A. Bouhlel, J. T. Hwang, N. Bartoli, R. Lafage, J. Morlier, J .R.R.A Martins (2019), A Python surrogate modeling framework with derivatives, Advances in Engineering Software

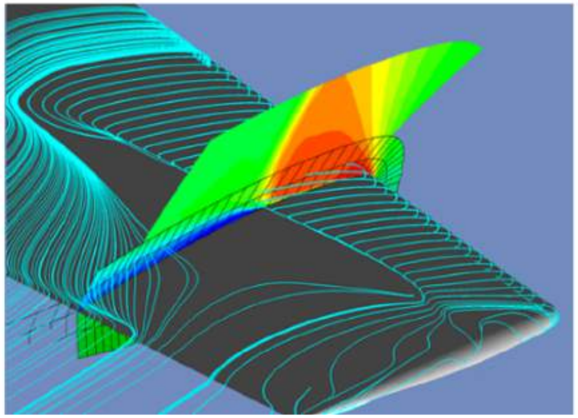
What if ?

Several levels of fidelity of the same simulation are available

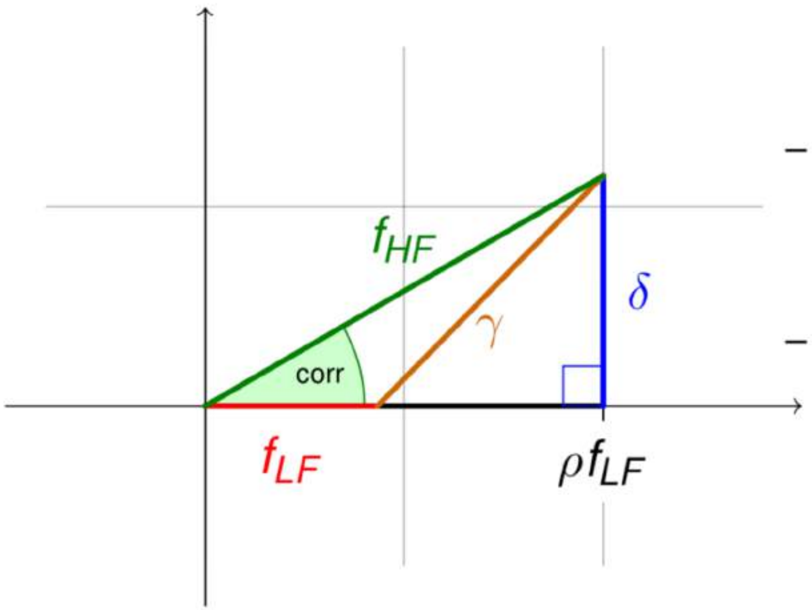
→ For example, in aerodynamics: Liflting line theory, Vortex lattice method, and RANS CFD code







Co Kriging



– Additive formulation [Lewis 2000]

$$f_{HF}(x) = f_{LF}(x) + \gamma(x)$$

– Kennedy-O'Hagan [Kennedy 2001]

$$\begin{cases} f_{HF}(x) = \rho f_{LF}(x) + \delta(x) \\ f_{LF}(\cdot) \perp \delta(\cdot) \end{cases}$$

The addition of the term ρ makes the multi-fidelity learning more robust to poor correlation as well as differences in modelisation.

$Alexandrov, N., Lewis, R., Gumbert, C., Green, L., & Newman, P. (2000, January). Optimization with variable-fidelity models applied to wing design. In 38th Aerospace Sciences Meeting and Exhibit (p. 841).

Kennedy, M. C., & O'Hagan, A. (2001). Bayesian calibration of computer models. Journal of the Royal Statistical Society: Series B (Statistical Methodology), 63(3), 425-464.

Lam, R., Allaire, D. L., & Willcox, K. E. (2015). Multifidelity optimization using statistical surrogate modeling for non-hierarchical information sources. In 56th AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference (p. 0143).

→ It is also away to learn the difference between HF & LF …

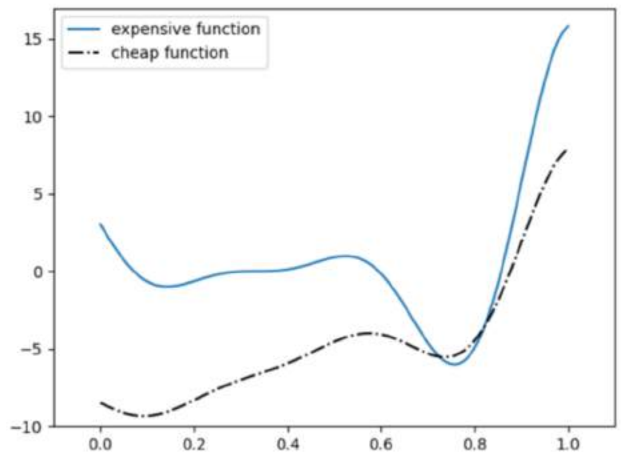
MFEGO 2 steps approach

- Most promising point: EI-based criterion

$$\mathbf{x}^* = \arg\max_{\mathbf{x}} \left(\mathrm{EI}(\mathbf{x})\right)$$

- Choice of levels of enrichment: trade off information gain/cost

$$k^* = \arg \max_{k \in (0,\ldots,\ell)} \frac{\sigma^2_{\mathrm{red}}(k, \mathbf{x}^*)}{\mathrm{cost}_{\mathrm{total}}(k)^2}$$

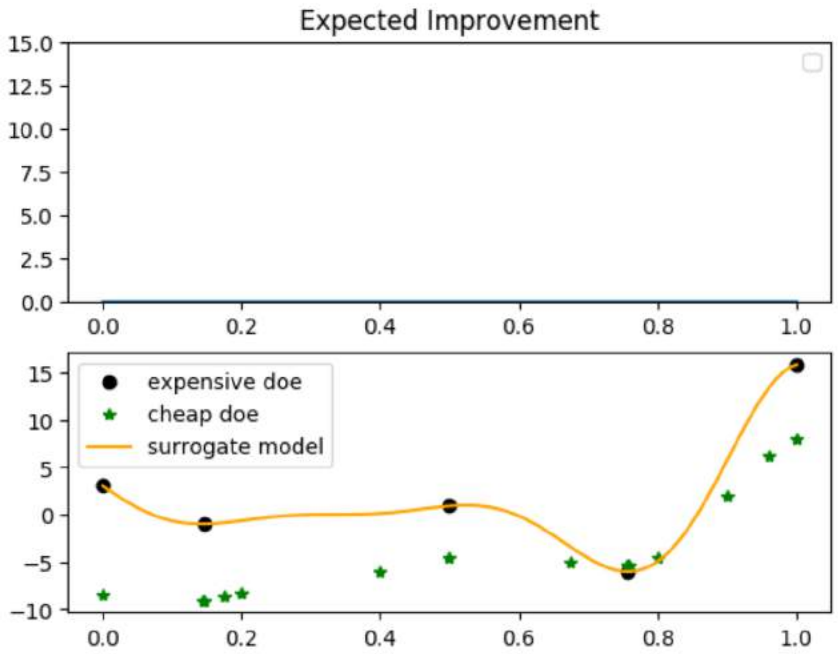


⇒ By using low-fidelity to reduce the uncertainty we reduce the Exploration contribution to the EI criterion

$$f_{HF}(x) = (6x-2)^2 \times \sin(2(6x-2))$$
$$f_{LF}(x) = 0.5 f_{HF} + 10(x-0.5) - 5$$

⇒ High-fidelity is used for Exploitation and model enhancement

Results (Toy problem)



Cost ratio: 1/1000

	HF	LF	Cost
MFEGO	3+2	6+9	5.015
EGO	4+11	-	15

Constrained Optimization

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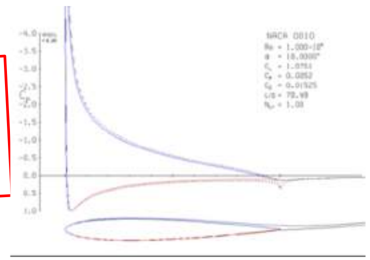
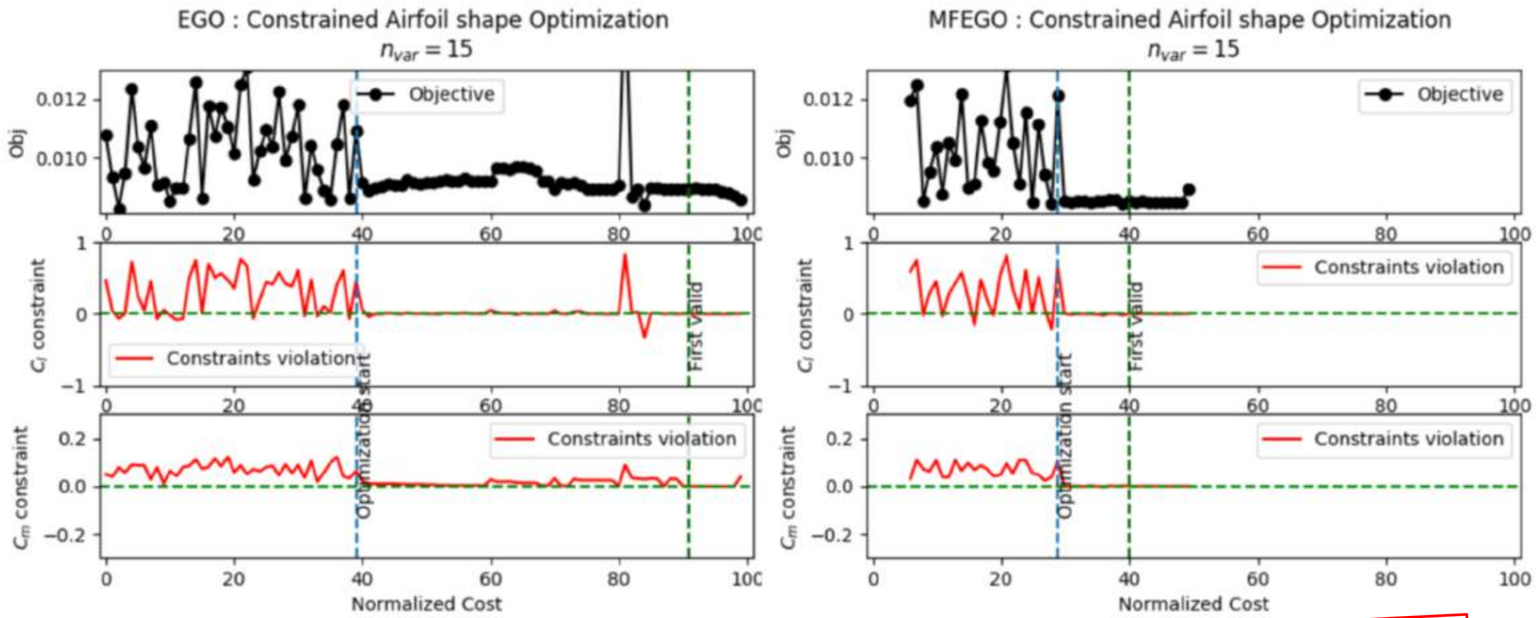


Estimated COST RATIO: 1/200



*https://web.mit.edu/drela/Public/web/xfoil/
$ http://mdolab.engin.umich.edu

MFEGO can speed up the Optimization process by reducing the calls to HF expensive code !

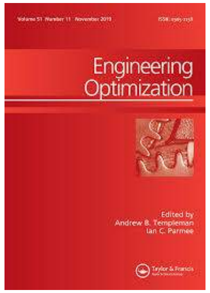
Conclusions on SMT

- « Reducing » industrial (**&costly**) simulation code is interesting to exchange data (without having access to the code) in a collaborative project (see AGILE…).
- Given its focus on **derivatives**, SMT is synergistic with the OpenMDAO framework. It can provide the derivatives that OpenMDAO requires from its components to compute the coupled derivatives of the multidisciplinary model.
- OpenMDAO/SMT is a natural framework for Bayesian/Surrogate based Optimization/Multifideility (**Low DV number !**)
- SMT core capabilities (KPLS) has been adapted for Surrogate based Optimization for mixed variables in OpenMDAO

→ See examples from Roy *et al* 2019

Roy, S., Crossley, W. A., Moore, K. T., Gray, J. S., & Martins, J. R. (2019). Monolithic Approach for Next-Generation Aircraft Design Considering Airline Operations and Economics. Journal of Aircraft, 56(4), 1565-1576.

Recent Papers on this topic



Bouhlel, M. A., Bartoli, N., Otsmane, A., & Morlier, J. (2016). Improving kriging surrogates of high-dimensional design models by Partial Least Squares dimension reduction. Structural and Multidisciplinary Optimization, 53(5), 935-952.

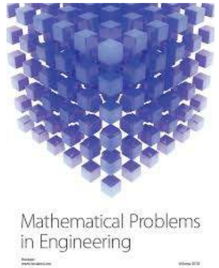
Bouhlel, M. A., Bartoli, N., Otsmane, A., & Morlier, J. (2016). An improved approach for estimating the hyperparameters of the kriging model for high-dimensional problems through the partial least squares method. Mathematical Problems in Engineering, 2016.

Bouhlel, M., Bartoli, N., Regis, R. G., Otsmane, A., & Morlier, J. (2018). Efficient global optimization for high-dimensional constrained problems by using the Kriging models combined with the partial least squares method. Engineering Optimization, 1-16.

Bouhlel, M. A., Hwang, J. T., Bartoli, N., Lafage, R., Morlier, J., & Martins, J. R. (2019). A Python surrogate modeling framework with derivatives. Advances in Engineering Software, 102662.

Bartoli, N., Lefebvre, T., Dubreuil, S., Olivanti, R., Priem, R., Bons, N, Martins, J. R. & Morlier, J. (2019). Adaptive modeling strategy for constrained global optimization with application to aerodynamic wing design. Aerospace Science and technology, 90, 85-102.

Bartoli, N., Meliani, M., Morlier, J., Lefebvre, T., Bouhlel, M. A., & Martins, J. (2019). Multi-fidelity efficient global optimization: Methodology and application to airfoil shape design. In AIAA Aviation 2019 Forum (p. 3236).



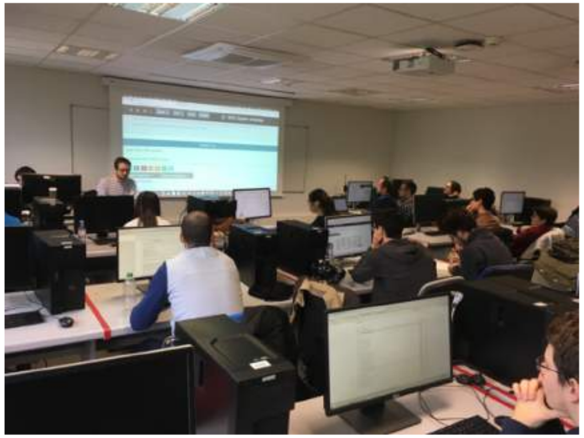
Outlines for today

1. Starting point X_0
2. Examples
3. Synergy with SMT

4. Classrooms and add-ons

5. Conclusion and future works

MDO courses & seminars



Thanks to Imco Van Gent, TU Delft

MULTIDISCIPLINARY OPTIMIZATION (MDO)							1MAE805
							(Anciens codes : 1MAE505-1MAE704)
SEANCES	DATES	HORAIRES Déb.	HORAIRES Fin	Total heures	Salles	Groupes	INTERVENANTS
C1	lundi 6 mai 2019	09h15	10h15	1	11 134		MORLIER Joseph
C2-C3		10h30	12h45	2	61 009 61 010		
BE1	mardi 7 mai 2019	14h00	16h15	2	61 009 61 010		
C4-C5	lundi 13 mai 2019	13h30	15h45	2	61 005 61 006		P.J. BARHJOUX, M. Herraz
PC1		11h45	12h45	1			
cours	jeudi 16 mai 2019	09h15	11h30	2	61 001 61 002		BARTOLI Nathalie LEFEBVRE THIERRY
cours	lundi 20 mai 2019	08h00	10H00	2	61 010 61 011		Loic Brevault, Mathieu Ballesdent
BE2	lundi 20 mai 2019	10h15	12h30	2	61 001 61 002		BARTOLI Nathalie LEFEBVRE THIERRY
BE3	vendredi 24 mai 2019	08h00	12h30	4	61 009 61 012		BARTOLI Nathalie LEFEBVRE THIERRY
C6	lundi 27 mai 2019	09h15	10h15	1	61 010		MORIO Jérôme
PC2		10h30	11h30	1			
C7	mardi 28 mai 2019	09h15	10h15	1	11 116		P.J. BARJHOUX
PC3		10h30	11h30	1			MAS COLOMER Joan CONIGLIO Simone
C8-C9	mercredi 29 mai 2019	14h00	16h15	2	11 116		C. GOGU
PC4		16h30	17h30	1			
BE5	lundi 3 juin 2019	09h15	12h30	3	61 009 61 010		C. GOGU
PC5-PC6	mercredi 5 juin 2019	09h15	11h30	2	61 009 61 010		MORIO Jérôme

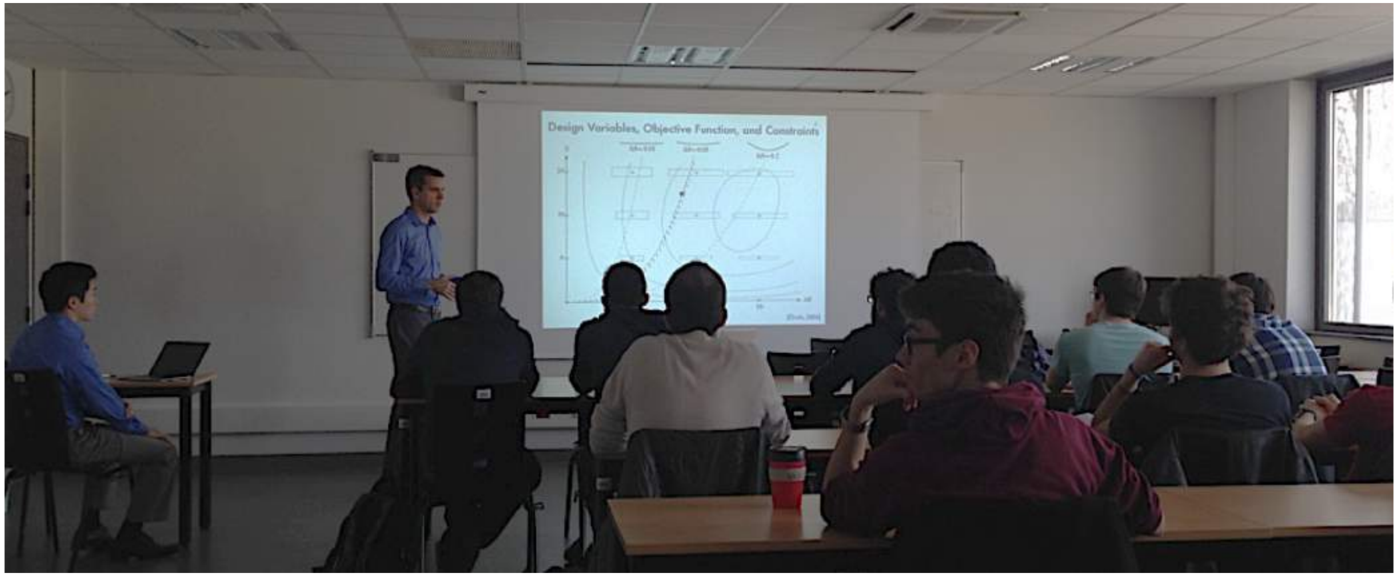
Sensitivity of finite element code
Continuous optimization (local/global)
Structural and topology Optimization
Response surface methods /DOE/SMT
Monte Carlo methods
Uncertainty propagation
Variance reduction
Bayesian Optimization
Reduced Order Modeling
MDA

Introduction to MDO+OpenMDAO (9h)

TOTAL=30H

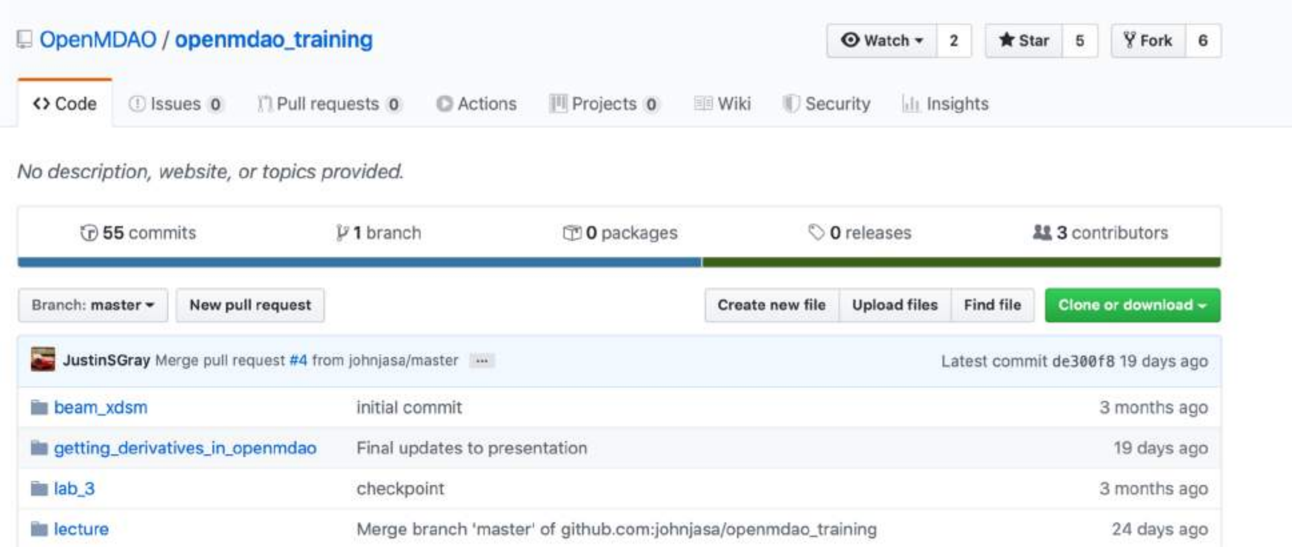
Since 2014 …OpenMDAO course at SUPAERO

Supaero engineering 's program *(15+ students) since 2014*
Master MAE (25+ students) since 2016



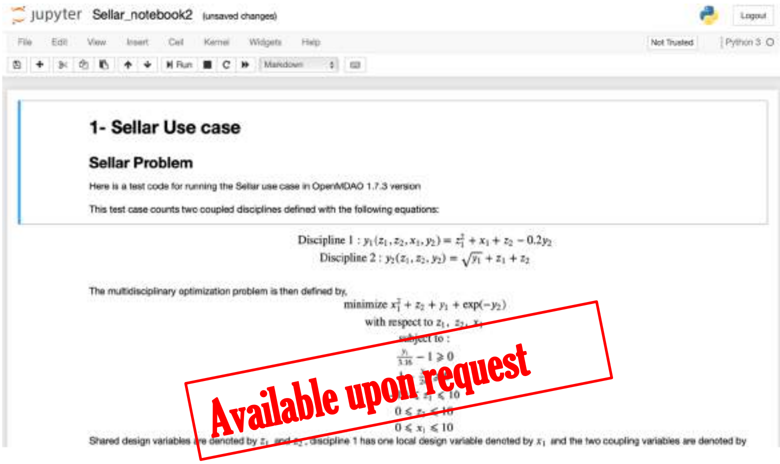
Why OpenMDAO?

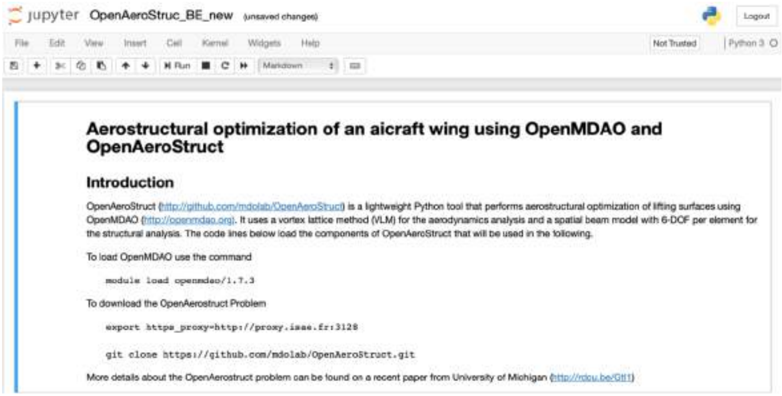
- Exists since 2010
- Stable since V2.0
- NASA team support (5+)
- Colllaboration with UoM, Purdue ....



Jupyter Notebooks*

- Sellar
- SSBJ
- OAS
- Launcher design project based on FELIN
https://github.com/M2CI-ONERA/FELIN





Short Courses for PhDs:

- Nice documentation for OM to start)!
- Coupling with DYMOS is really nteresting for us

Project-based learning: AGILE ACADEMY

Université Fédérale Toulouse Midi-Pyrénées

GROUPE ISAE

ISAE SUPAERO

EXCELLENCE WITH PASSION

ABOUT ISAE-SUPAERO ACADEMICS ADMISSION

from europe and north america.

In order to check if the AGILE paradigm was usable outside of the project, the AGILE partners create **the AGILE Academy challenge**. The aim was to perform the job of an aircraft design t AGILE tools. **36 students from 4 continents** enter the challenge. They were divided into three February to july 2018, the three teams design the aircraft with the help of the partners.

At the end of the challenge, **the winner team**, composed by Andrew Jerayaj (Concordia Univ Earnest (Concordia University), Ezhil Shakti Murugesan (Concordia University), marco picchi s University), Florian Sanchez (Bombardier and Concordia University), Karim Abusalem (Pisa Un **Priem Remy (ONERA and ISAE-SUPAERO), RODRIGUEZ-OTERO Pablo (ISAE-SUPAERO)**, M Amine Ben Salah Bouhlel (Michigan University), designed **a regional aircraft improved by so power sources.**

They were invited to the AGILE Meeting in Naples to present their Work to all the agile Partne

MORE INFORMATION :

https://www.agile-project.eu/agile-challenge

MID2

Multidisciplinary optimization for Innovation : Design and Data

SUPAERO

Repositories 38 | Packages | People 37 | Teams

Prof. J. Morlier

joseph.morlier@isae-supaero.fr

40+ Students In MDO Courses At Master Level

In 2019 We Developed New Methodologies (or Applications) In :

Computational Structural Mechanics

#Gaussian Processes For Linear Elasticity

#Geometric Projection In Topology Optimization (AIRBUS and ICA)

#Topology Optimization For 3Dprinting (AIRBUS and ICA)

#High Resolution Topology Optimization (AIRBUS and ICA)

#Levet Set For Automatic Fiber Placement

#Eco Material Selection

#1D Refined FE Model In Dynamics

#IsoGeometric Analysis (LAMCOS and IMT)

Multidisciplinary Design Optimization

#HALE Ecodesign (CEDAR Chair)

#Reusable Launchers (SACLAB Chair)

#Multifidelity Method with Gaussian Processes (ONERA and MDOlab)*

#MDA Acceleration

#Codesign For Robust Flutter (AIRBUS)

#Trajectory Control

#Gaussian Processes and POD for coupled problem (ONERA)

#Aeroelastic for Scaled Aircraft (CEDAR Chair, ONERA and MDOlab)

#Hybrid Optimization (AIRBUS And IRT)

#BWB (CEDAR Chair, ONERA)

Thanks To All Supaero's Students (MAE, PIR, PhDs And Postdoc)

* https://smt.readthedocs.io/en/latest/

ADD-ONS (1) https://github.com/OneraHub/WhatsOpt

Fichier Édition Affichage Historique Marque-pages Outils ?

WhatsOpt

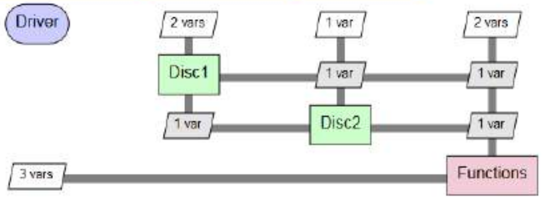
selene.onecert.fr/whatsopt/analyses/1

WhatsOpt Analyses Notebooks Hangar Redmine

Sellar

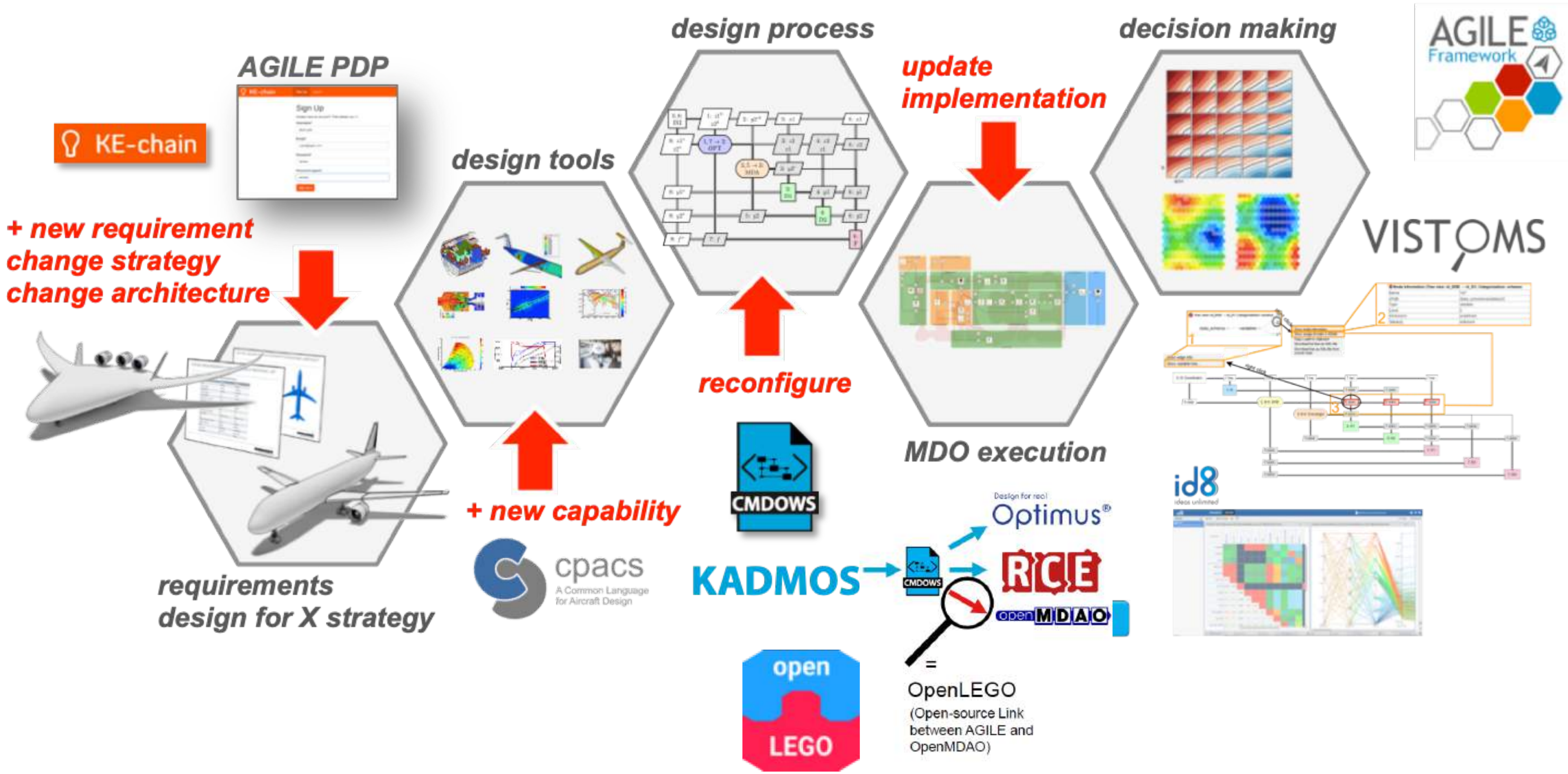
Edit Operate Delete Close

OpenMDAO Export | Cmdows Export | Image Export



From	To	Name	Role	Type	Shape	Units	Init	Lower	Upper
Functions	Driver	g1	Neg Constraint	Float	1				
Functions	Driver	g2	Neg Constraint	Float	1				
Functions	Driver	obj	Min Objective	Float	1				
Driver	Disc1, Functions	x	Design Variable	Float	1		2	0	10
Disc1	Disc2, Functions	y1	State Variable	Float	1				
Disc2	Disc1, Functions	y2	State Variable	Float	1				
Driver	Disc1, Disc2, Functions	z	Design Variable	Float	(2,)		[5., 2.]	0	10

ADD-ONS (2) http://www.agile-project.eu



Outlines for today

1. Starting point X_0
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Conclusions

- MDO is the core of our Air/Craft Design researches at ONERA and SUPAERO→ SBO can facilitate the exploration of new concepts

EGO on SMT

- The multifidelity / Mixture of experts (MOE) options help us to speed the process (ongoing work)

MFK, MOE on SMT

- MDO concepts and technologies disseminated from university to aerospace industry

→ New generation of engineers with MDO skills

- Open questions:

→Optimizer for hybrid design variables (continuous, discrete, categorical …)?

→Link with Manufacturing and MBSE

January 11th, 2019 - The follow-on project **"AGILE 4.0"** has been accepted by the European Commission.

AGILE 4.0

AGILE 4.0 will start around mid-2019 and will extend the outcomes of the **AGILE** project to cover all the aspects of the development of complex aeronautical systems, including design, certification and manufacturing.

On Thursday MDO PhD day

…and in July 2020

\# mixed continuous integer design variables

\# optimal trajectory control

\# {vehicle + mission} design

\# Codesign …

Minisymposium about Multifidelity Optimization during the joint WCCM/ECCOMAS events. (reference MS442 Multifidelity Optimization https://www.wccm-eccomas2020.org/frontal/MSList.asp)

The conference will take place in Paris (19th to 24th of July 2020). More details about the conference is available on the website

https://www.wccm-eccomas2020.org/frontal/introduction.asp

MDO PhD day - 21 November 2019 - ISAE-SUPAERO

Time	Session	Title	Presenter
08:30 – 09:00	*Arrival & Coffee*		
09:00 - 09:10	Welcome & Introduction		Grégoire Casalis (ISAE – SUPAERO)
09:10 - 09:30	MDO Applications Chair: T. Lefebvre	"Exploration of a Blended Wing-Body concept featuring distributed electric propulsion with gradient optimization techniques"	Alessandro Sgueglia (ONERA / ISAE - SUPAERO)
09:30 - 09:50		"Multidisciplinary Design Optimization of a Reusable Lunar Vehicle "	Laurent Beauregard (ICA / ISAE - SUPAERO)
09:50- 10:10		"MDO for representative sub-scale flight Testing"	Akshay Raju Kulkarni, Anne-Liza Bruggeman (TUD)
10:10 - 10:30		"Tool path optimization for free form surfaces machining"	Mahfoud Herraz (ENAC /ICA)
10:30 - 10:50	*Coffee Break*		
10:50 - 11:10	MDO Aero-structure focus Chair: J. Morlier	"NeOPT: structural optimization in the conceptual design phase"	Francesco Toffol (POLIMI)
11:10 - 11:30		"HALE multidisciplinary design optimization with focus on Eco-Material selection"	Edouard Duriez (ISAE - SUPAERO)
11:30 – 11:50		"Transonic flight and movables loads modelling for preliminary aeroservoelastic MDO of a wing box"	Paul Lancelot (TUD)
11:50 – 12:10		"Some computational aspects of active flutter suppression for co-design"	Emeline Faisse (ISAE – SUPAERO / AIRBUS)
12:10 – 12:30		"High-fidelity aerodynamic shape optimization of wind turbine blades"	Mads Holst Aagaard Madsen (DTU)
12:30 – 14:00	*Lunch & Coffee*		
14:00 - 14:20	MDO Methods Chair: Y. Diouane	"Recent MDO Lab activities"	Neil Wu (UM - MDO Lab)
14:20 - 14:40		"Optimizing System Architectures by Leveraging Collaborative MDO"	Jasper Bussemaker (DLR)
14:40 - 15:00		"Inclusion of discrete technological choices in design optimization process within a Bayesian framework"	Julien Pelamatti (ONERA)
15:00 - 15:20		"On a feasibility criterion for aircraft efficient global multidisciplinary optimization"	Rémy Priem (ONERA / ISAE - SUPAERO)
15:20 - 15:40		"Robust multidisciplinary design optimization applied to long range aircraft under operational uncertainty"	Nicolas Peteilh (ENAC)
15:40 - 16:00	Conclusion		J. Morlier (ISAE – SUPAERO)
16:00	*Coffee Break*		
16:30	*End of the Day*		

NEW CHALLENGE (0) with IRT SE for Airbus

Continuous

e.g.:
area, thickness

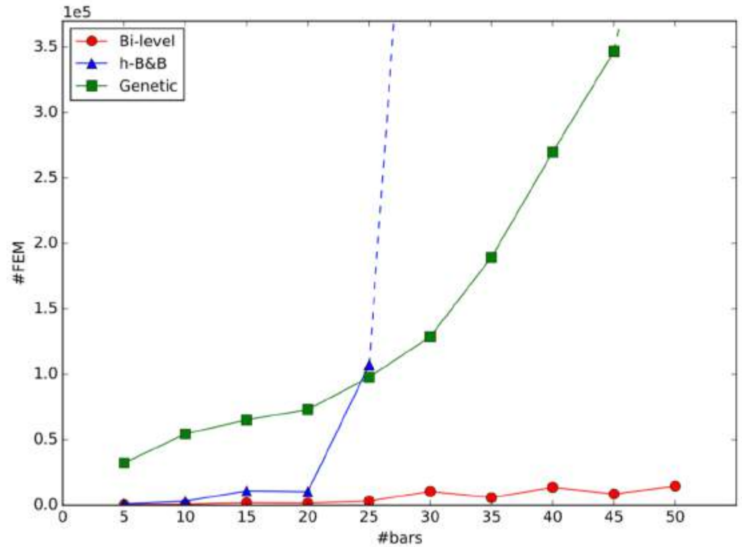
Non-ordered categorical

e.g.:
cross-section, material

Structural Multidisciplinary Optimization manuscript No.
(will be inserted by the editor)

A bi-level scalable methodology for mixed categorical-continuous structural optimization problems

Pierre-Jean Barjhoux · Youssef Diouane · Stéphane Grihon · Dimitri Bettebghor · Joseph Morlier

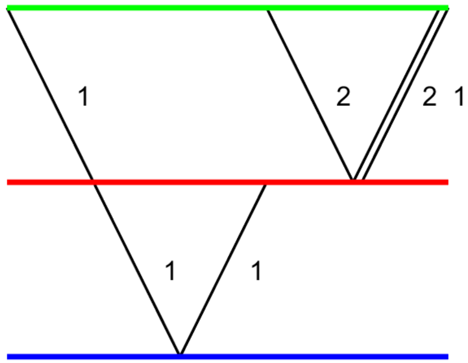


NEW CHALLENGE (1) with AIRBUS DS/ Ariane Group

SAC LAB

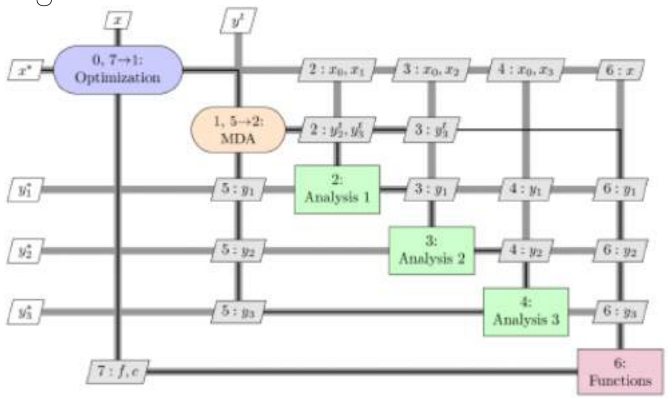
Mission architecture analysis

Enumerate the possible mission architectures and rank them



Multidisciplinary design optimization (MDO)

Use OpenMDAO methodology for preliminary design of reusable lunar lander

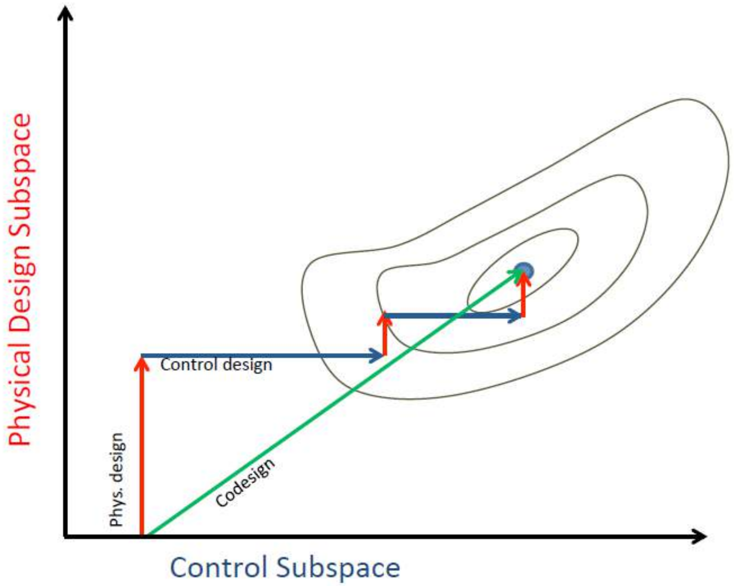


Multidisciplinary architecture design optimization

NEW CHALLENGE (2) with AIRBUS (Aircraft)

Navigate in physical and control design subspaces simultaneously.

→ Tailor structural/mechanical/control system designs: system optimality



Deshmukh, A. P., & Allison, J. T. (2016). Multidisciplinary dynamic optimization of horizontal axis wind turbine design. Structural and Multidisciplinary Optimization, 53(1), 15-27.

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