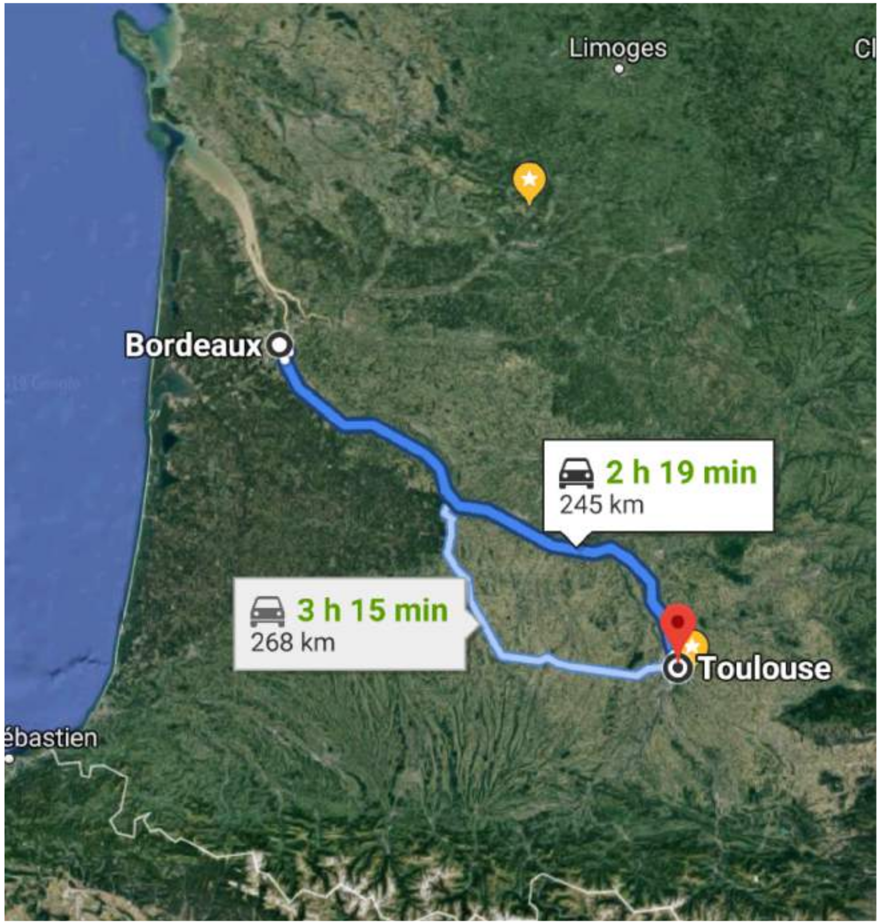
How do we use openMDAO in our Research activities

and also in classrooms…

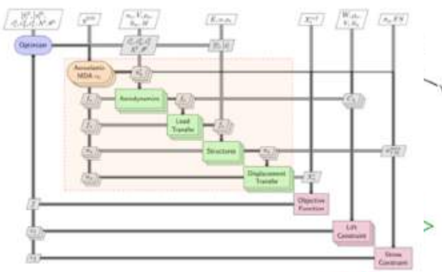
Nathalie Bartoli, Thierry Lefebvre, Joseph Morlier

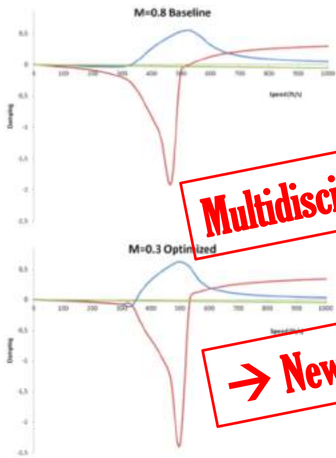
PhD in Bordeaux then… Toulouse



Who am I ?

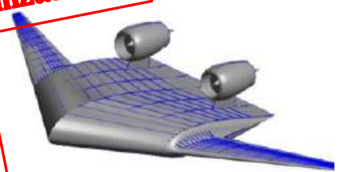
- 4 PhDs, 1 postdoc, 1 research assistant, 4 MsCs

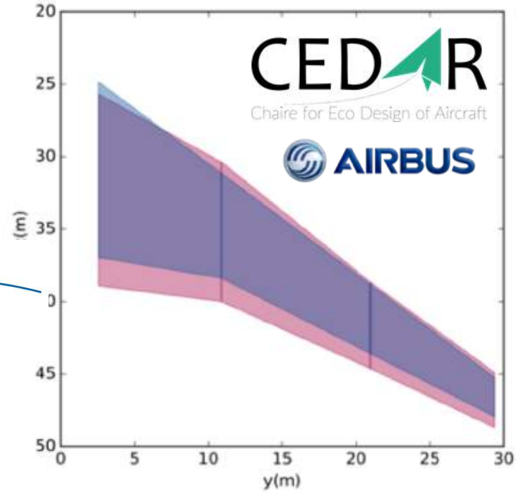




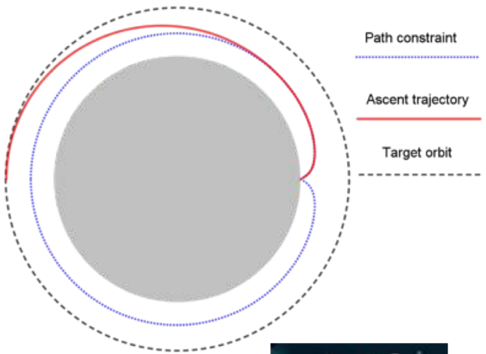
Multidisciplinary Design Optimization

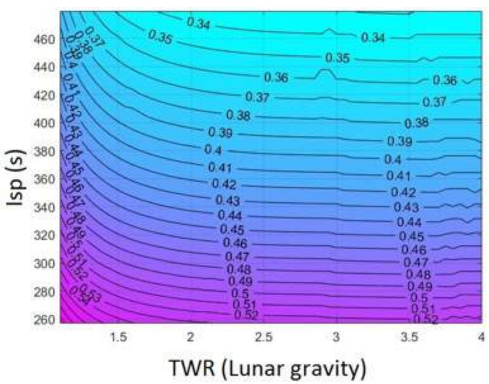
→ New Aircraft Concept





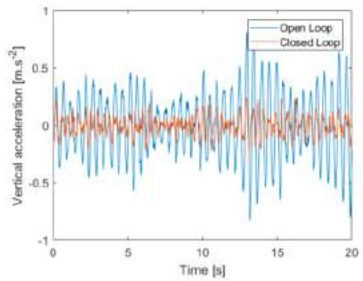
Optimized planform (red) and baseline (blue).





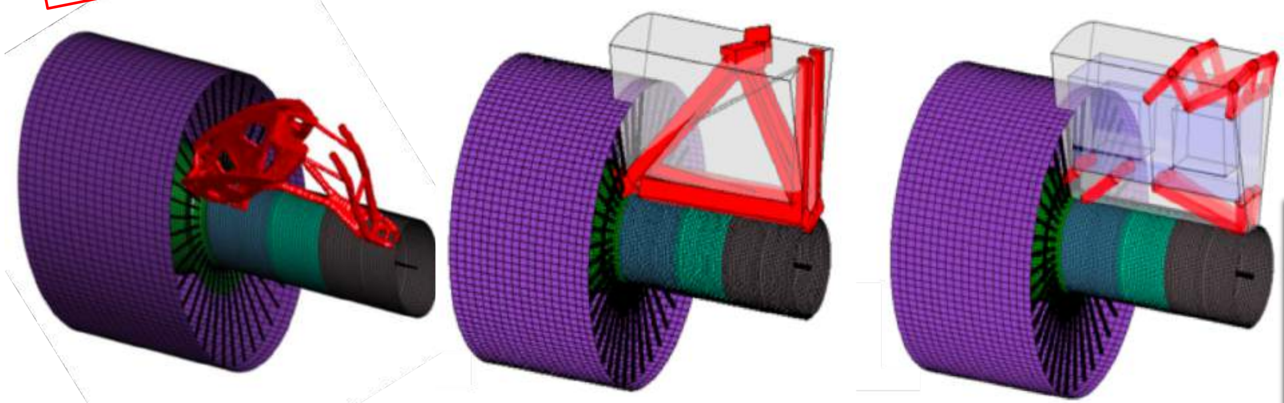
New disciplines
← trajectory
or
control →

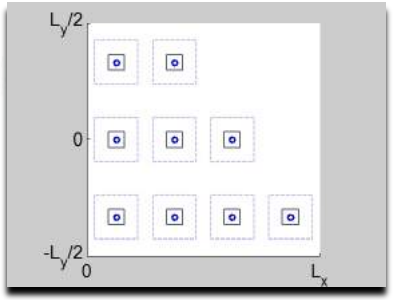
minimize	$f(x) = w_1 k_h + w_2 \bar{h}_{max}(t, V_f^{CL})$
with	$x = (k_h, Q, R)$[4]
subject to	$V_f^{CL} > 1.2\, V_{f\,x_0}^{OL}$ $\lvert \beta_{max}(t, V_f^{CL}) \rvert < \beta_{ref}$ $f^i_{max} < 3 f^i_{max\,x_0}$
where	V_f^{XL} is the open loop (OL) or closed loop (CL) flutter velocity at the current iteration β_{ref} is the maximum control surface deflection f^i_{max} 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



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

Topology Optimization



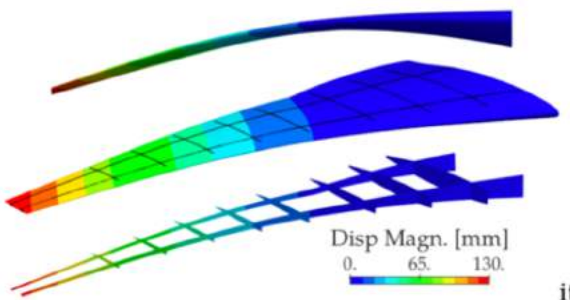


AIRBUS

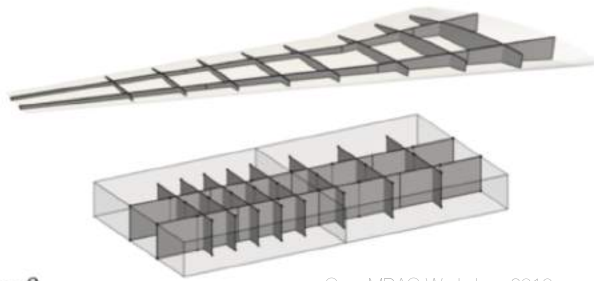
AIRBUS

Isogeometric Optimization

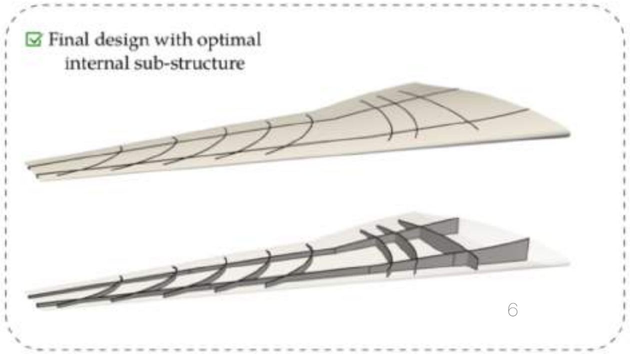
http://www.institut-clement-ader.org/pageperso.php?id=jmorlier



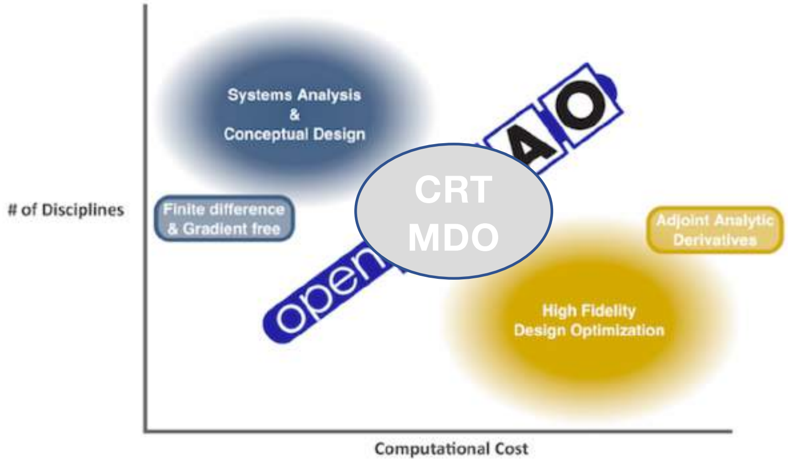
iter 0



LaMCoS Unité Mixte de Recherche 5259



Common Research Team (ONERA+SUPAERO+ENAC) :



CRT 10+ researchers

Speaker	Institute		
Session		Presentation	Thursday 12/10
V. Wiels & P. Bidaud	ONERA	Welcome and introduction to ONERA - scientific roadmap	9h30-10h
J. Gray	NASA	OpenMDAO Historic - Generic presentation	10h- 12h30
J. Hwang	NASA	Maud - OpenMDAO 2.0 - Applications	
			Lunch break
Session		OpenMDAO Framework -Users' perspective	
S. Defoort	ONERA	ACADIA project : ONERA MDAO framework approach	13h45-14h15
P.D. Ciampa	DLR	AGILE project : a collaborative MDO approach (interface with OpenMDAO)	14h15-14h45
Session		Applications - Use cases	
L. Brevault & M. Balesdent	ONERA	Preliminary study on launch vehicle design with OpenMDAO	14h45-15h15
P.D. Ciampa	DLR	MDO architectures: a comparison study of MDO platforms	15h15-15h45
			Coffee Break
S. Delbecq, Ch. Corsi, M. Budinger	INSA	OpenMDAO and the predesign of embedded mechatronic equipments	16h15-16h45
J. Morlier, J. Mas Colomer, N. Bartoli, T. Lefebvre	ISAE-ONERA	Static and Dynami... M Wing vi... Mu...	
C. Br...			
Session			
R. Lafage	ONERA	ACADIA ... e	
I. van Gant	TUDelft	Link...	
J. Gray & J. Hwang	NASA + All	user request / Future develpment / OpenMDAO Roadmap 2017--20XX	10h30-12h
			lunch break

toulouse 13 10 17 Onera

1st European OpenMDAO Workshop – Octobre 2017 - ONERA

Outlines for today

#EfficientGlobalOptimization
#Multifidelity
#Typeofdesignvariables
#Classrooms

1. How do we start with OM?
2. Examples
3. Synergy with SMT
4. Classrooms and add-ons
5. Conclusion and future works

Outlines for today

1. How do we start with OM?

2. Exemples
3. Synergy with SMT
4. Classrooms and add-ons
5. Conclusion and future works

Our 1st contribution

- Vauclin, R. (2014). Développement de modèles réduits multifidélité en vue de l'optimisation de structures aéronautiques. Rapport ISAE-SUPAERO

Thanks to Rémi Lafage (ONERA)

- But we really use it from the begining…

OpenMDAO 2.9.0 Beta documentation » Source Docs » openmdao.surrogate_models »

multifi_cokriging.py

Integrates the Multi-Fidelity Co-Kriging method described in [LeGratiet2013].

(Author: Remi Vauclin vauclin.remi@gmail.com)

This code was implemented using the package scikit-learn as basis. (Author: Vincent Dubourg, vincent.dubourg@gmail.com)

OpenMDAO adaptation. Regression and correlation functions were directly copied from scikit-learn package here to avoid scikit-learn dependency. (Author: Remi Lafage, remi.lafage@onera.fr)

ISAE/DMSM - ONERA/DCPS

class `openmdao.surrogate_models.multifi_cokriging.`**`MultiFiCoKriging`**(*regr='constant', rho_regr='constant', normalize=True, theta=None, theta0=None, thetaL=None, thetaU=None*) [source]

Bases: `object`

Integrate the Multi-Fidelity Co-Kriging method described in [LeGratiet2013].

Notes

Implementation is based on the Package Scikit-Learn (Author: Vincent Dubourg, vincent.dubourg@gmail.com) which translates the DACE Matlab toolbox, see [Rafec0a633dc4-NLNS2002].

References

[Rafec0a633dc4-NLNS2002]H. B. Nielsen, S. N. Lophaven, and J. Sondergaard. `DACE - A MATLAB Kriging Toolbox`. (2002) http://www2.imm.dtu.dk/~hbn/dace/dace.pdf

Rafec0a633dc4-WBSWM1992W. J. Welch, R. J. Buck, J. Sacks, H. P. Wynn, T. J. Mitchell, and M. D. Morris (1992). "Screening, predicting, and computer experiments." `Technometrics`, 34(1) 15–25. http://www.jstor.org/pss/1269548

Rafec0a633dc4-LeGratiet2013L. Le Gratiet (2013). "Multi-fidelity Gaussian process regression for computer experiments." PhD thesis, Universite Paris-Diderot-Paris VII.

Rafec0a633dc4-TBKH2011Toal, D. J., Bressloff, N. W., Keane, A. J., & Holden, C. M. E. (2011). "The development of a hybridized particle swarm for kriging hyperparameter tuning." `Engineering optimization`, 43(6), 675–699.

Outlines for today

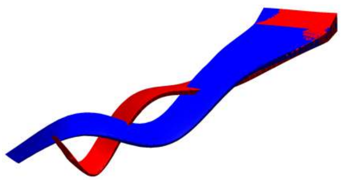
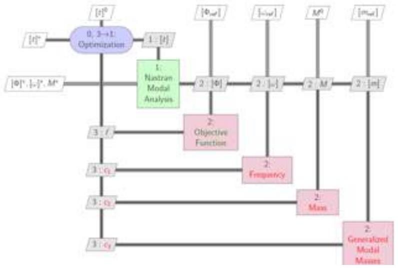
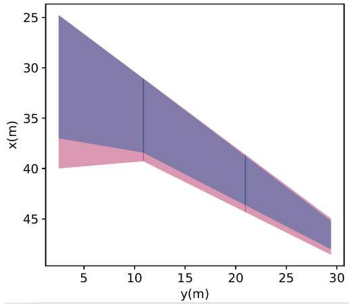
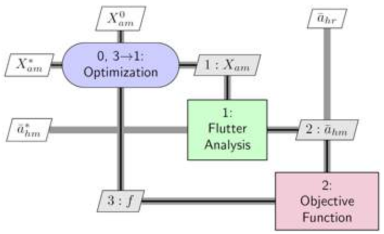
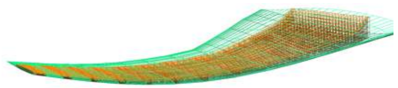
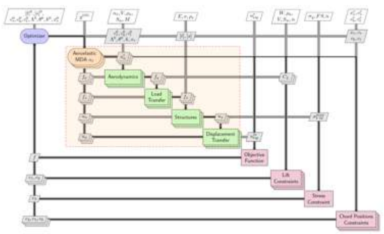
1. How do we start with OM?

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)

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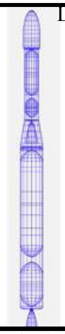
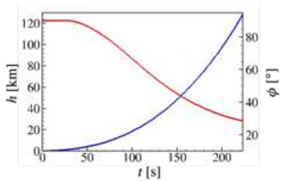
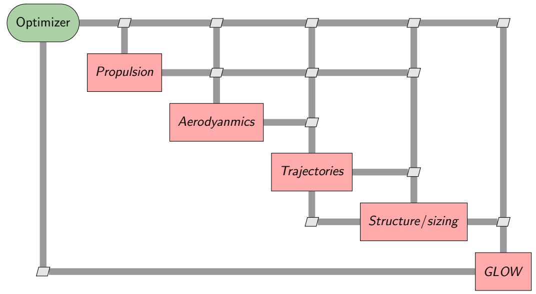
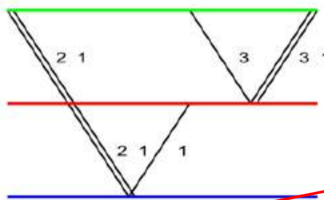
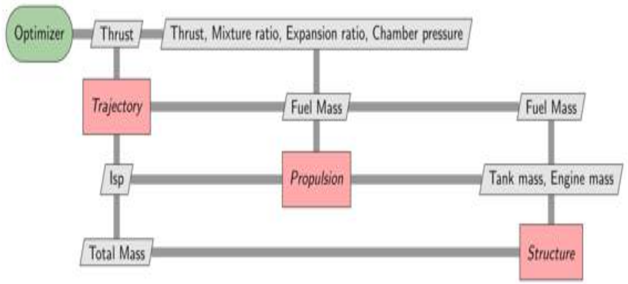
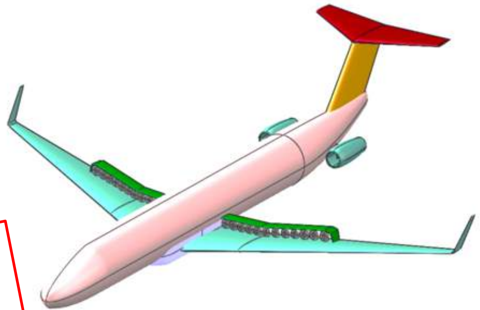
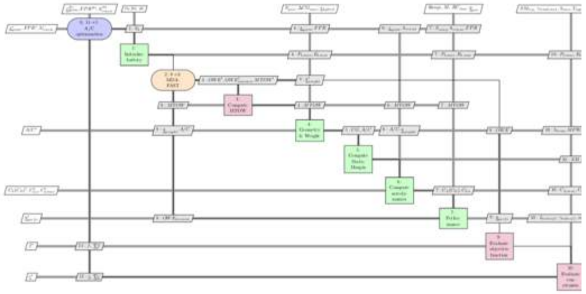
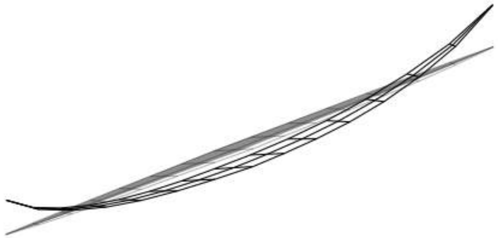
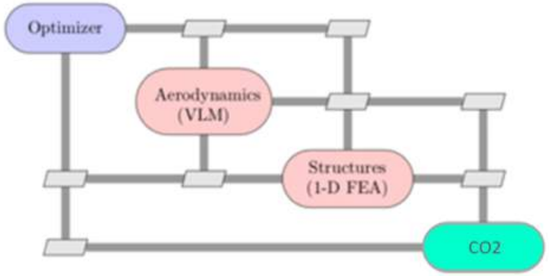
And more recently… for Space Application at SUPAERO

Problem	Model structure	Design variables	Objective	Constraints
 LAST : Launcher Analysis Sizing Tool ***Sizing and trajectory*** 		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]  Discrete variables		Thrust, type of fuel, mixture ratio, expansion ratio	Average mass used per mission	Thrust to weight ratio >1 for landing and take off

see Next Presentation for ONERA

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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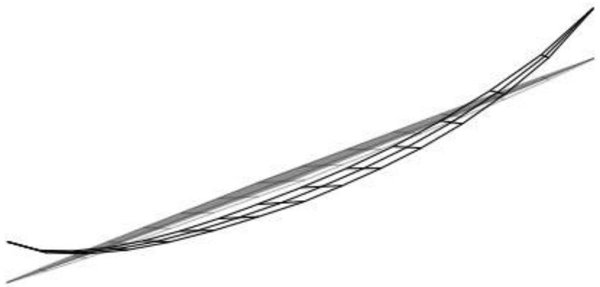
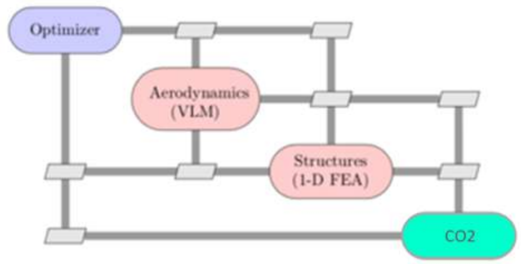
ECO Hale

Derive OAS 2.0 to treat a HALE pseudo sattelite Design problem

HALE ecodesign MDO		Thicknesses, twists, material, geometry	CO_2 footprint	Available power, stress, flight
				

<u>Assets:</u> Flexible, repositionable, permanent coverage, cheaper, lower environnemental impact?

Minimize CO2

w.r.t. thicknesses, twist, geometry,

Discrete variables

materials database CES EDUPACK *(CFRP-3, GFRP, ALU,…)*

Subject to Available solar power, stress, buckling, flight

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,

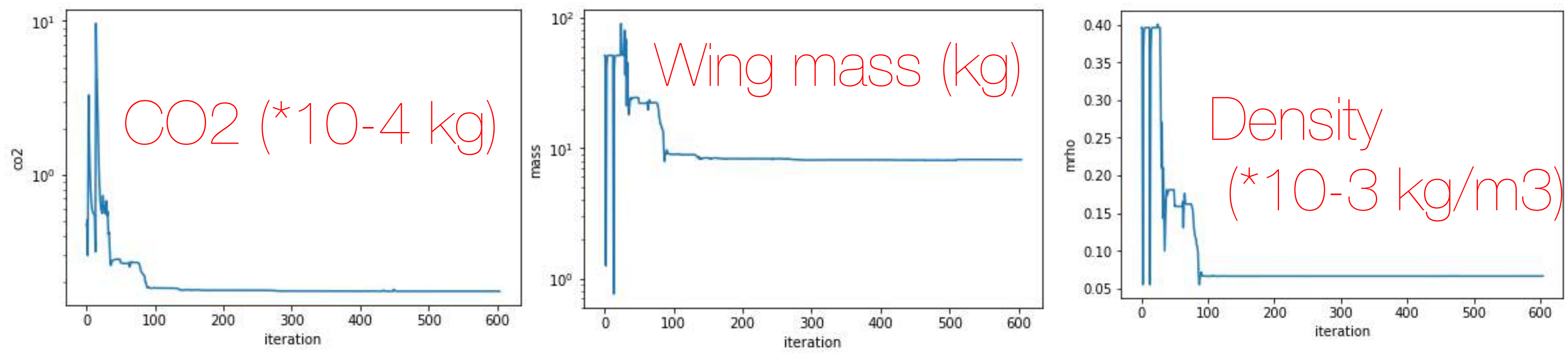
$$E_e(\rho_e) = A_E * \rho_e^p + B_E \quad \text{, with } A_E = \frac{E_i - E_{i+1}}{\rho_i^p - \rho_{i+1}^p} \text{ and } B_E = E_i - A_E * \rho_i^p$$

- 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

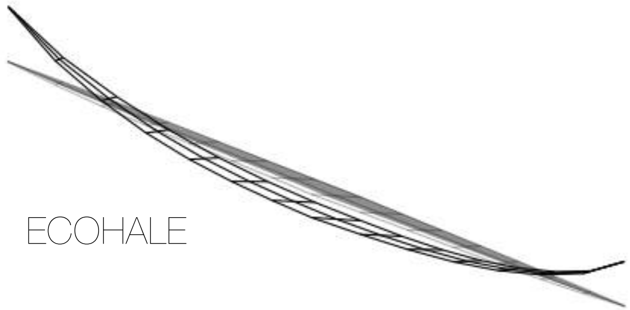


- The final material is a sandwich panel (UD CFRP – expanded PS foam – UD CFRP)
- The optimal material in terms of CO2 is very close to the optimal material in terms of weight, because battery is the most impacting on CO2

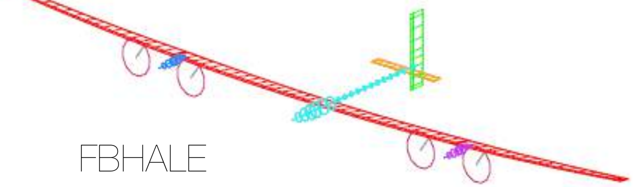
ECODESIGN IN THE MDO LOOP

- 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	Modified 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).

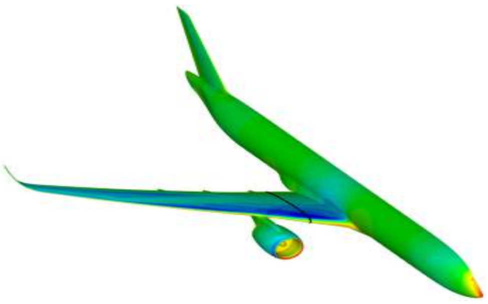
Outlines for today

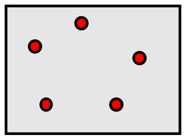
1. How do we start with OM?
2. Examples

3. Synergy with SMT

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

Surrogate modeling Recipes

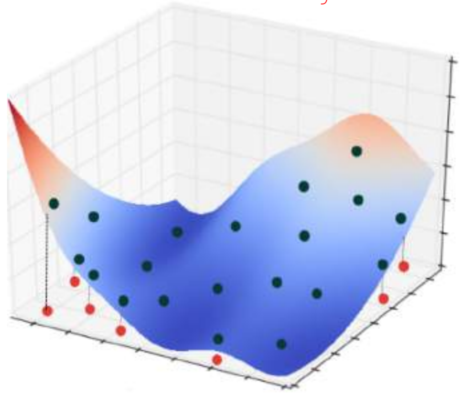


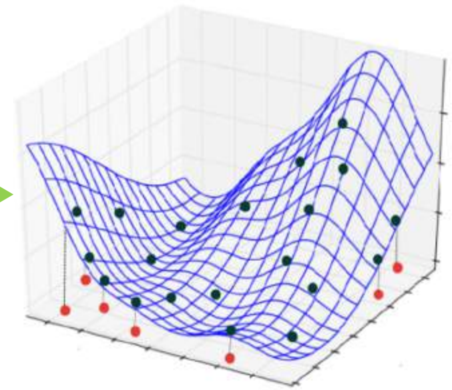


DOE

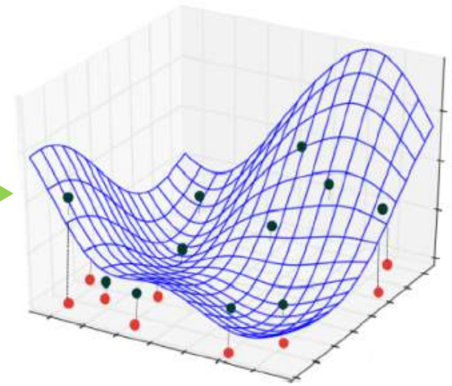
True Function Evaluation

This is costly!





Interpolant model



Regression model

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

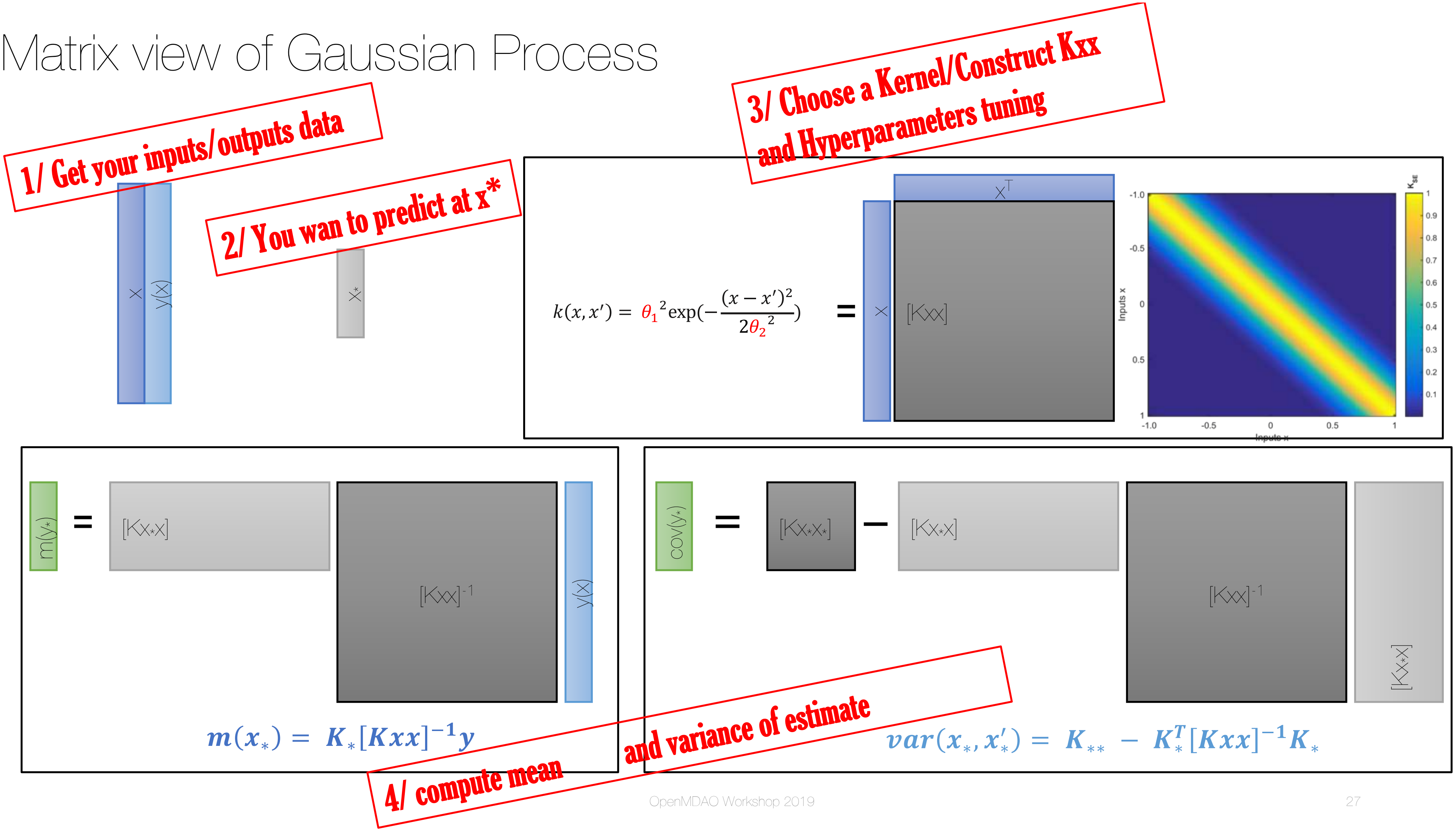
$$LOF = \frac{MSE}{Var(y)}$$

n is the number of samples

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

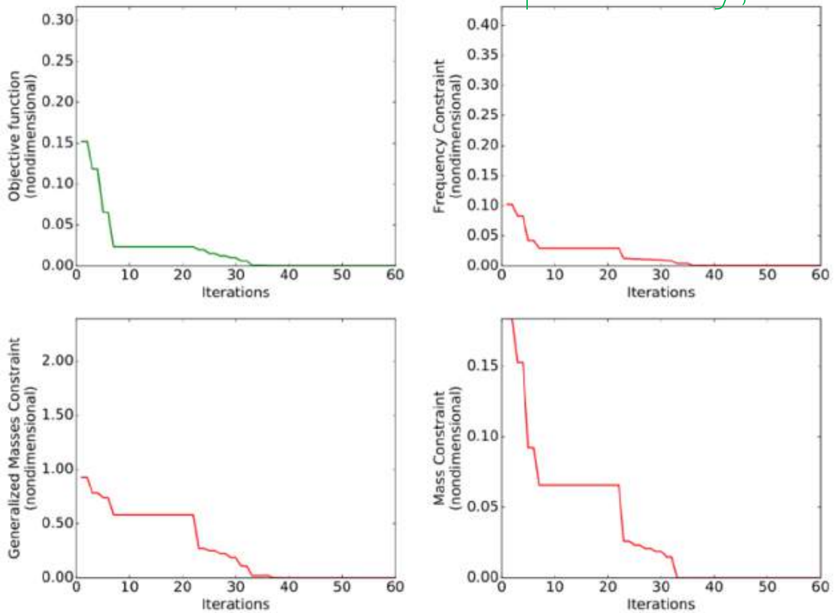
y is the true outputs of the n samples

Matrix view of Gaussian Process

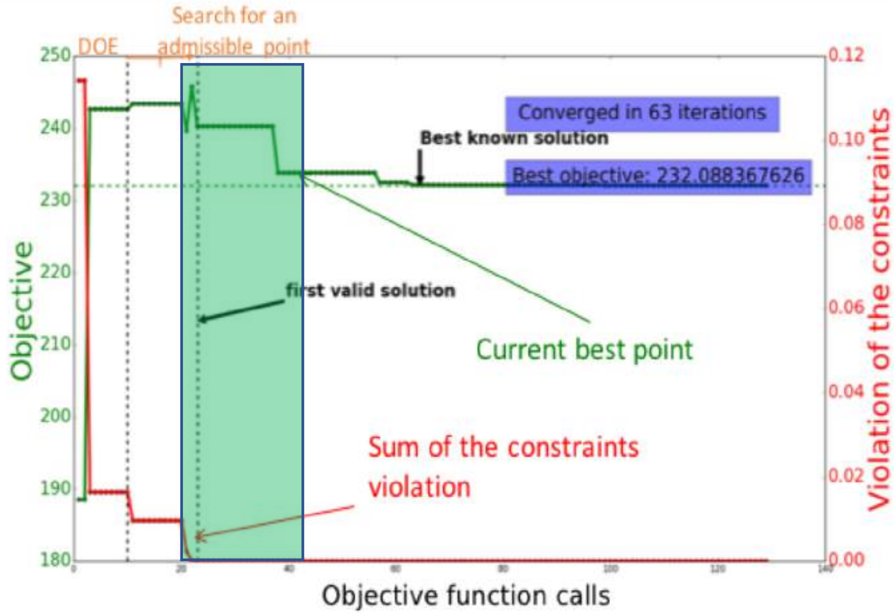


New graphs

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

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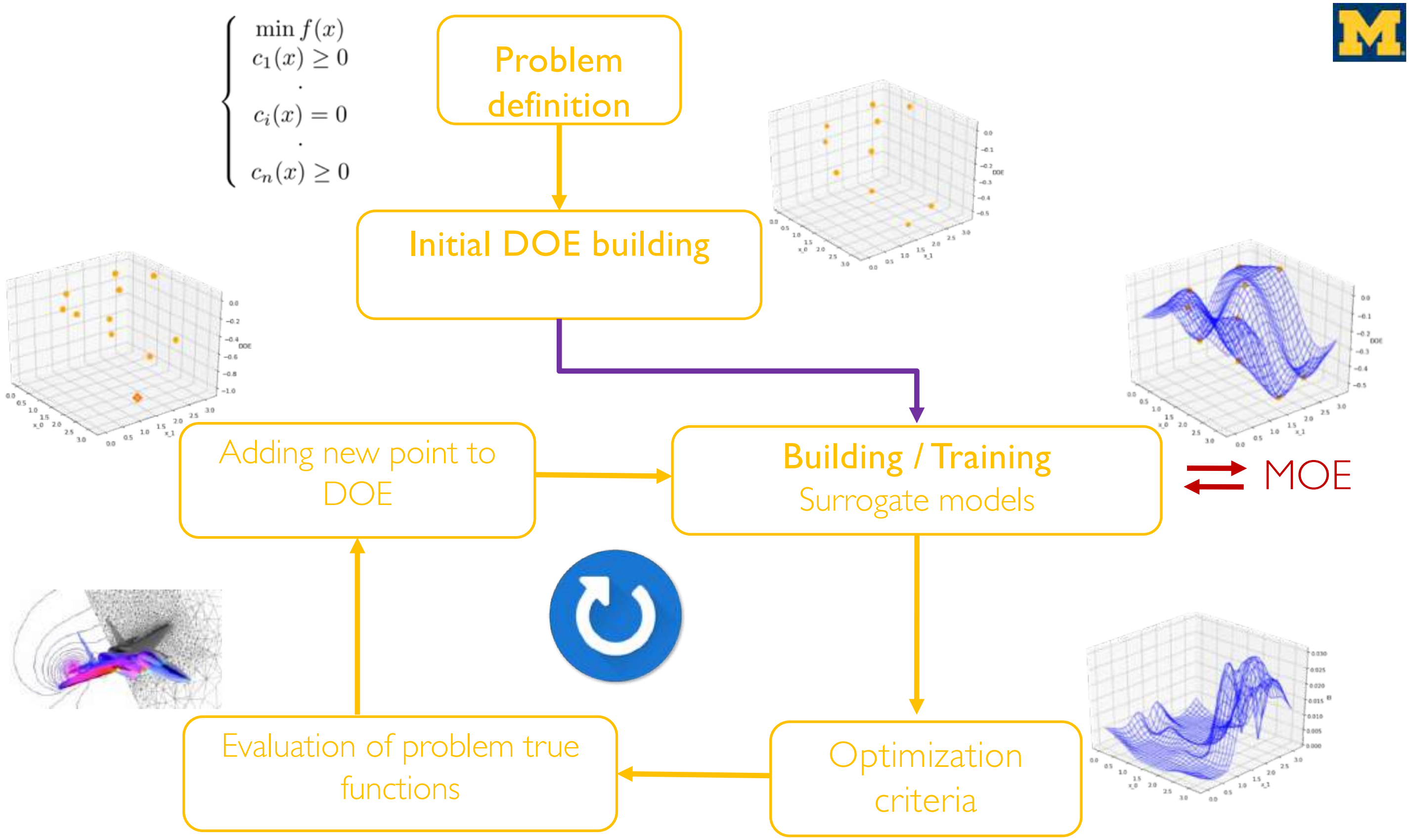
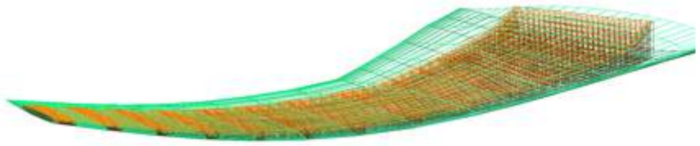
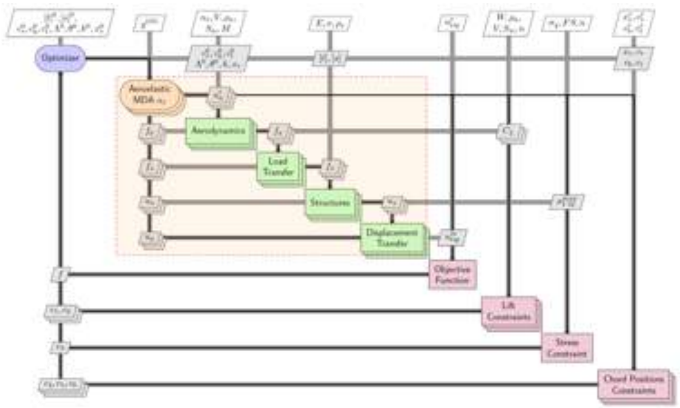


Static Optimization (SEGOMOE)

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

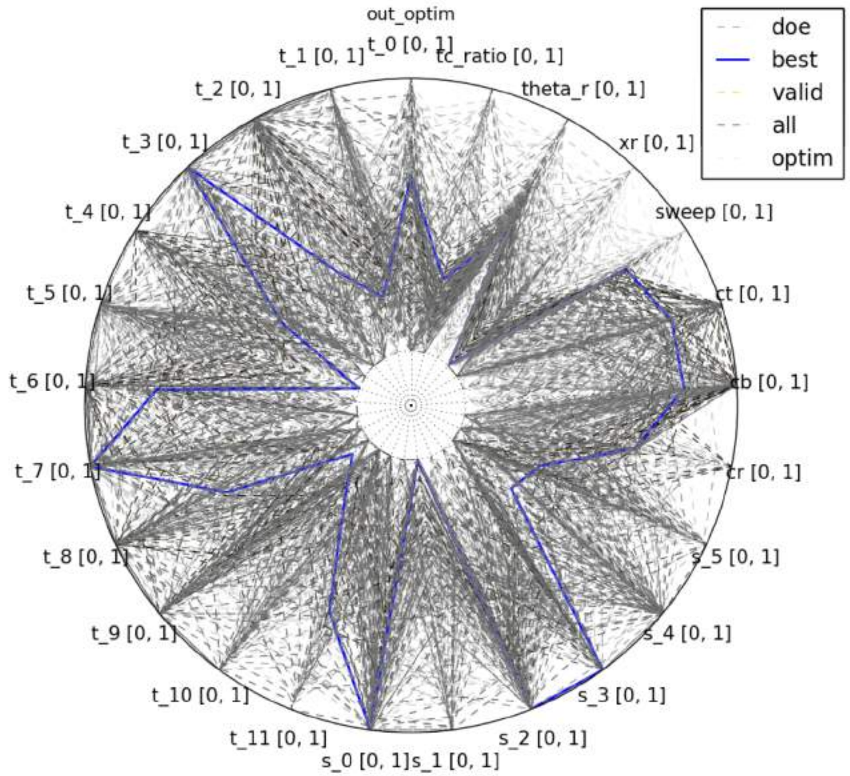
Design Variables

struct.
- Thicknesses vector
- Stringer section vector

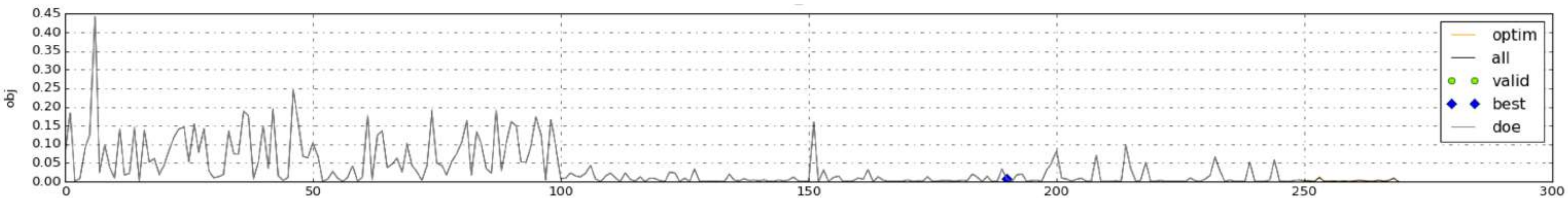
geom.
- Root chord
- Break chord
- Tip chord
- Sweep
- Wing mounting angle
- Root leading edge
- t/c scaling factor

Constraints

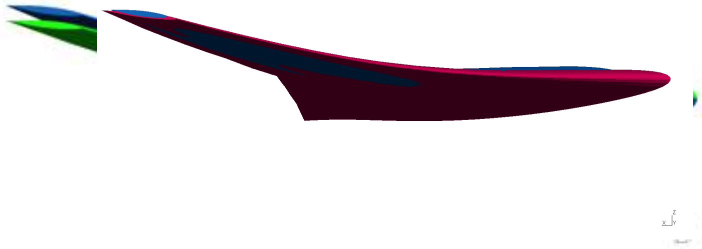
Lift constraints



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%

Wingtip **displacement** error: 1.5%

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

AEROSPACE ENGINEERING
UNIVERSITY of MICHIGAN

NASA

ISAE SUPAERO

ONERA
THE FRENCH AEROSPACE LAB

Thanks to Mohamed Bouhlel

Table of Contents

Next topic

Getting started

This Page

Show Source

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

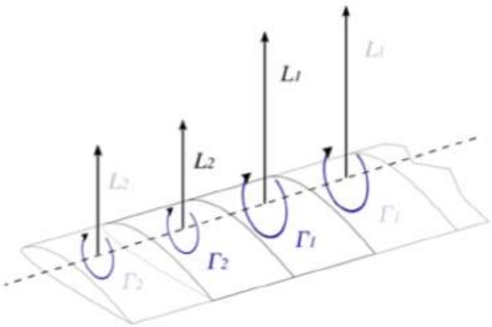
3 types of derivatives…

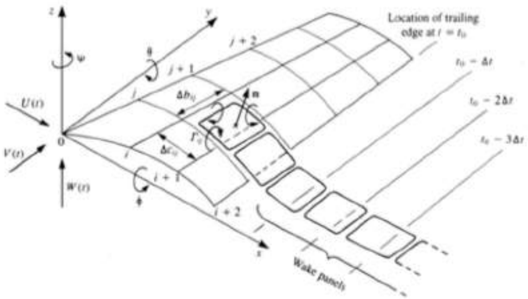
M.-A. Bouhlel, J. T. Hwang, N. Bartoli, R. Lafage, J. Morlier, J .R.R.A Martins (2019), A Python surrogate modeling framework with derivatives, Advances in Engineering Software

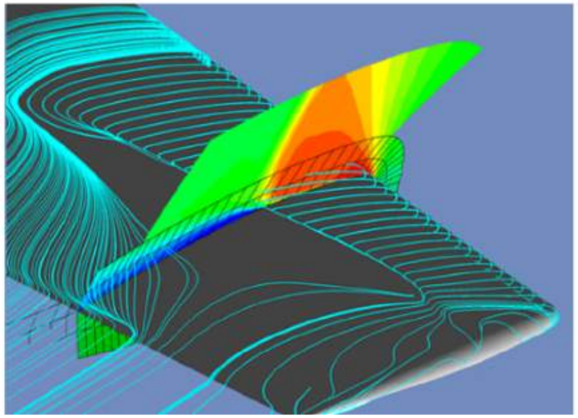
What if ?

Several levels of fidelity of the same simulation are available

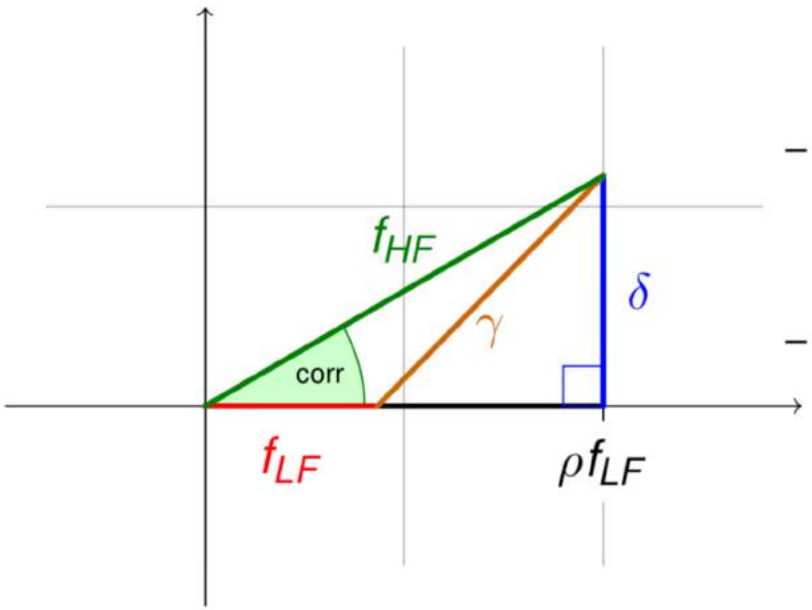
→ For example, in aerodynamics: Liflting line theory, Vortex lattice method, and RANS CFD code







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 …

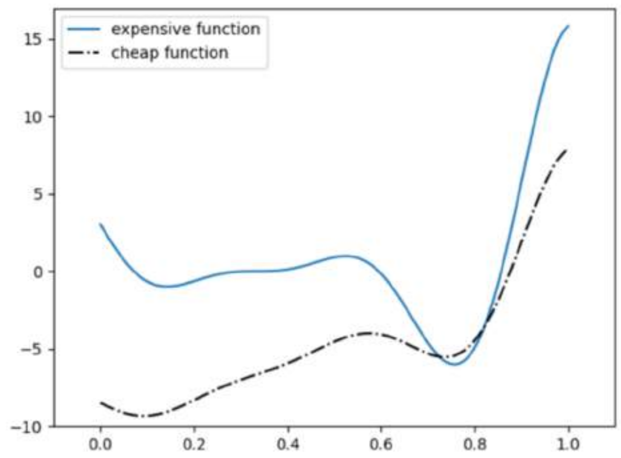
MFEGO 2 steps approach

- 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

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

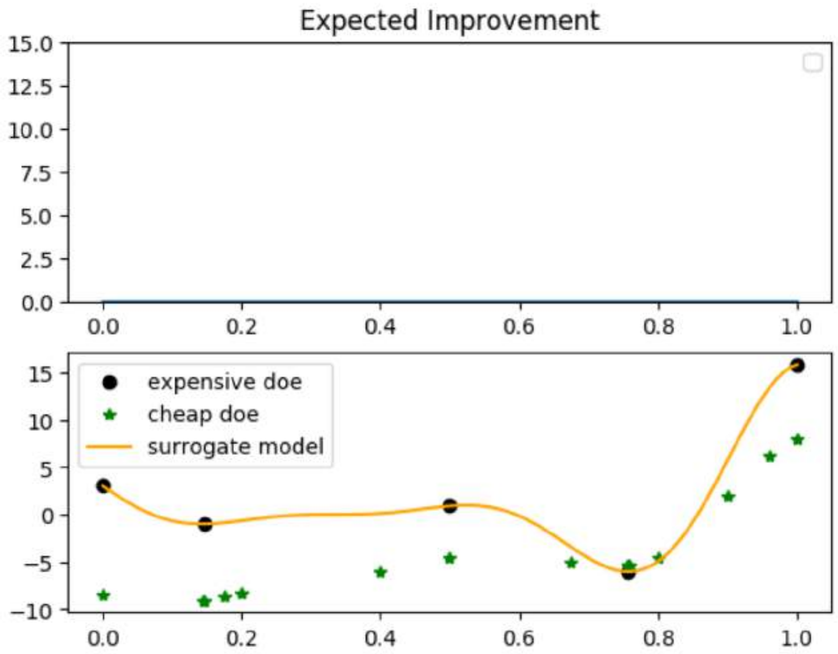


$\Rightarrow$ By using low-fidelity to reduce the uncertainty we reduce the Exploration contribution to the EI criterion

$\Rightarrow$ High-fidelity is used for Exploitation and model enhancement

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

Results (Toy problem)

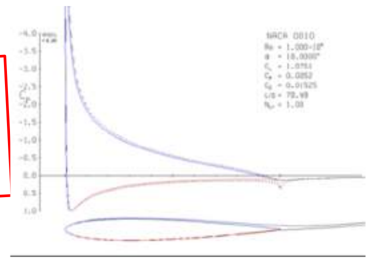


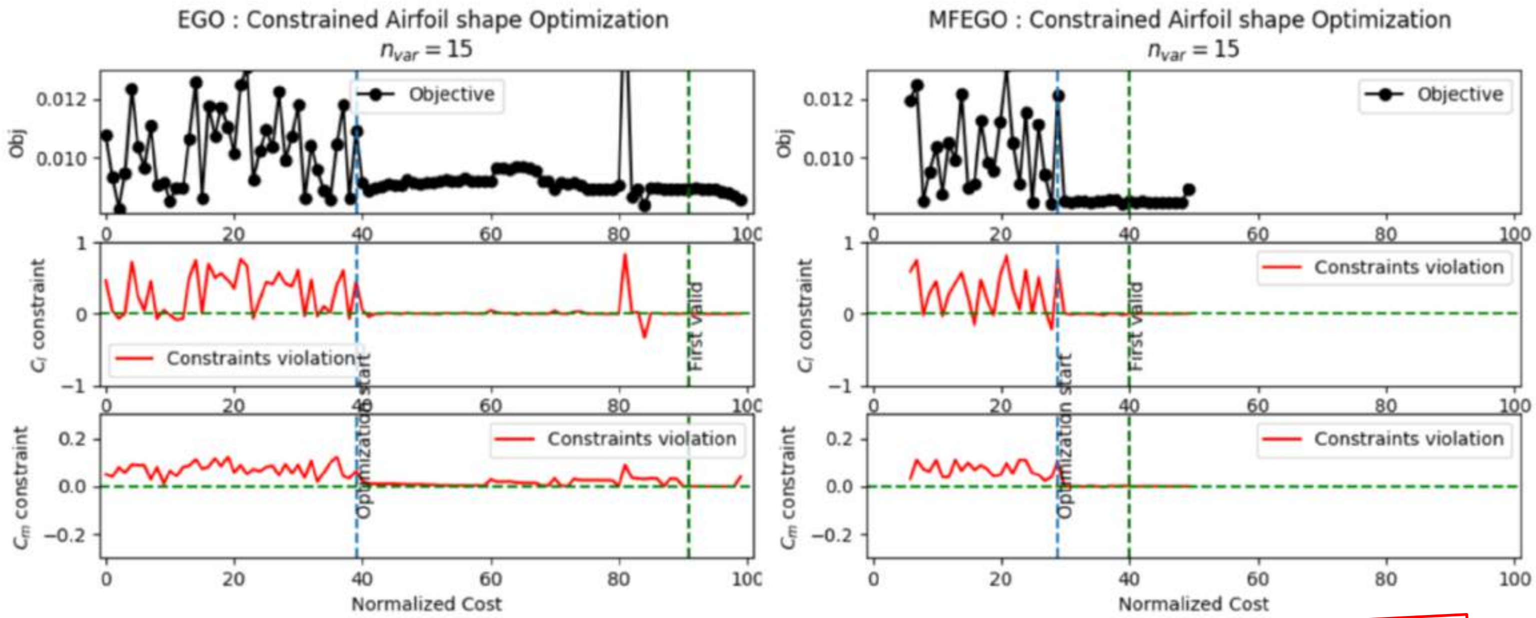
Cost ratio: 1/1000

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

Constrained Optimization

Estimated COST RATIO: 1/200





[*https://web.mit.edu/drela/Public/web/xfoil/](https://web.mit.edu/drela/Public/web/xfoil/)
[$ http://mdolab.engin.umich.edu](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.
- OM/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 OM

→ 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.

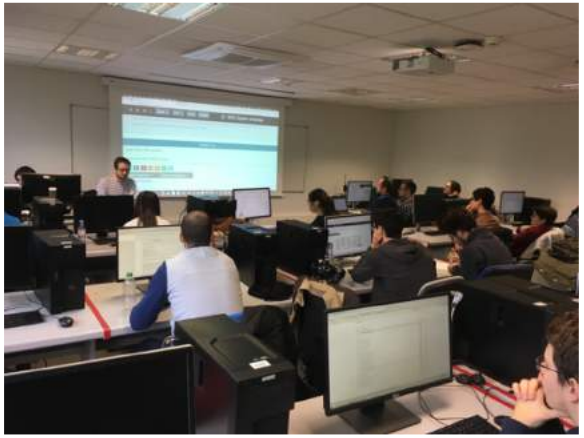
Outlines for today

1. How do we start with OM?
2. Exemples
3. Synergy with SMT

4. Classrooms and add-ons

5. Conclusion and future works

MDO courses & seminars



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)
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

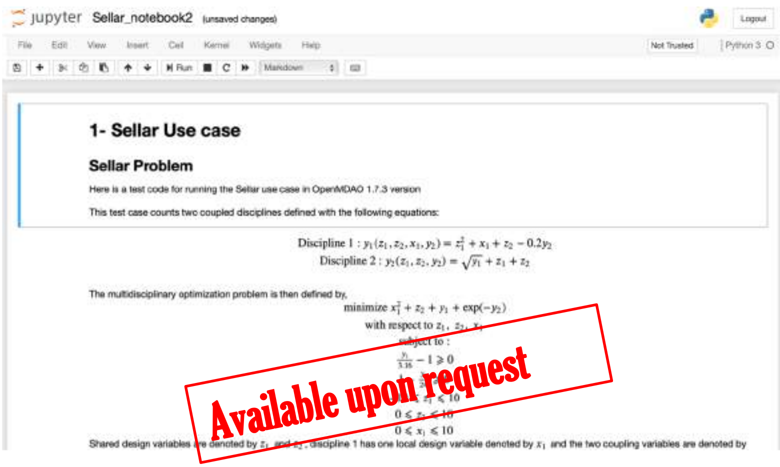
Jupyter Notebooks*

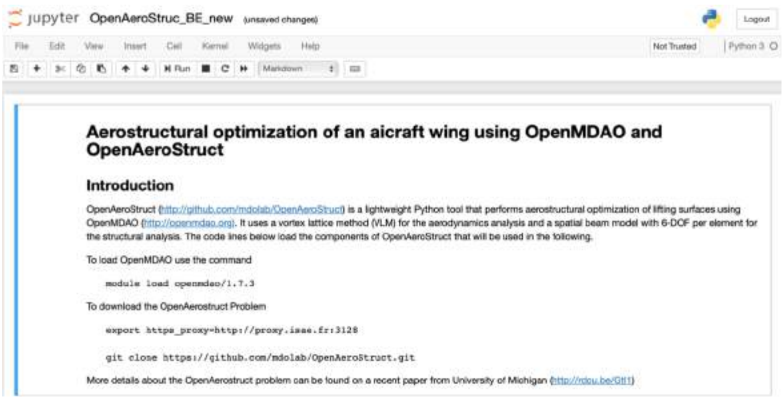
Supaero engineering 's program *(15+ students) since 2014*

Master MAE (25+ students) since 2016

- 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

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

Thierry Lefebvre • 1er
Research Scientist chez ONERA - The French Aerospace Lab
2 h • Tout le monde

WhatsOpt is going open source !

Happy to announce that WhatsOpt is open source and distributed under AGPLv3 license.

WhatsOpt is a Ruby on Rails web application allowing to define and share multi-disciplinary analyses in terms of disciplines and data exchange. It was developed to support overall vehicle design activities at ONERA.

#OpenMDAO framework is currently the execution framework used by WhatsOpt.

https://lnkd.in/d7F--Xc

OneraHub / WhatsOpt

Watch 1 | Star 2 | Fork 1

<> Code | Issues 1 | Pull requests 0 | Projects 0 | Security | Insights

WhatsOpt

WhatsOpt is a Ruby on Rails web application allowing to define and share multi-disciplinary analyses in terms of disciplines and data exchange. It was developed to support overall vehicle design activities at ONERA.

From this high-level modeling, users can generate source code skeleton required to plug the actual implementation of their disciplines and get an actual executable model of the vehicle concept under study. Users can also generate code to run numerical methods such as sensitivity analysis, design of experiments, metamodel construction and optimizations.

User resources

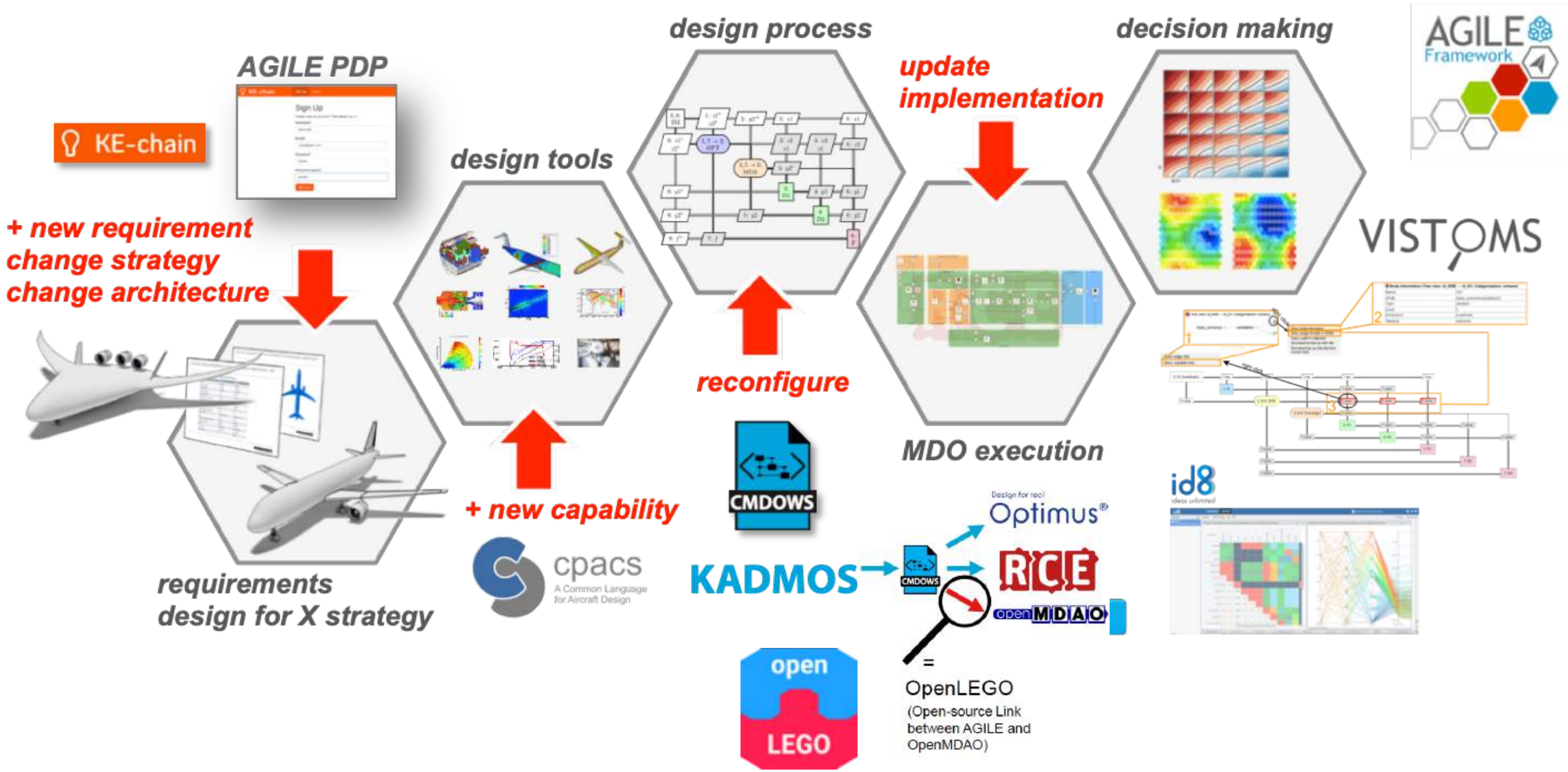
- WhatsOpt paper: WhatsOpt: a web application for multidisciplinary design analysis and optimization.
- WhatsOpt doc: Notebooks and examples
- WhatsOpt videos: Tutorials

Citation

If you happen to find WhatsOpt useful for your research, it will be appreciated if you cite us with:

> Lafage, R., Defoort, S., & Lefebvre, T. (2019). *WhatsOpt: a web application for multidisciplinary design analysis and optimization. In AIAA Aviation 2019 Forum (p. 2990).*

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



Outlines for today

1. How do we start with OM?
2. Examples
3. Synergy with SMT
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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

- Open questions:

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

→ New developments probably in Julia ?

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.

Thanks

to our co-workers:

Joaquim Martins, Mohamed-Amine Bouhlel, Rémi Lafage, Claudia Bruni, John Hwang, Joan Mas Colomer, Peter Schmollgruber, Youssef Diouane, Sylvain Dubreuil, Stéphanie Lisy-Destrez, Anna Federica Urbano, Emmanuel Benard,

and PhDs: Alessandro Sgueglia, Laurent Beauregard, Emeline Faisse, Edouard Duriez, Rémy Priem, Mostafa Meliiani