Authors' Note: USE THE LOGO AT THE FIRST SLIDE THAT'S ALL

How to ?

Write scientific papers
Make a presentation
Publish online

Prof. J. Morlier

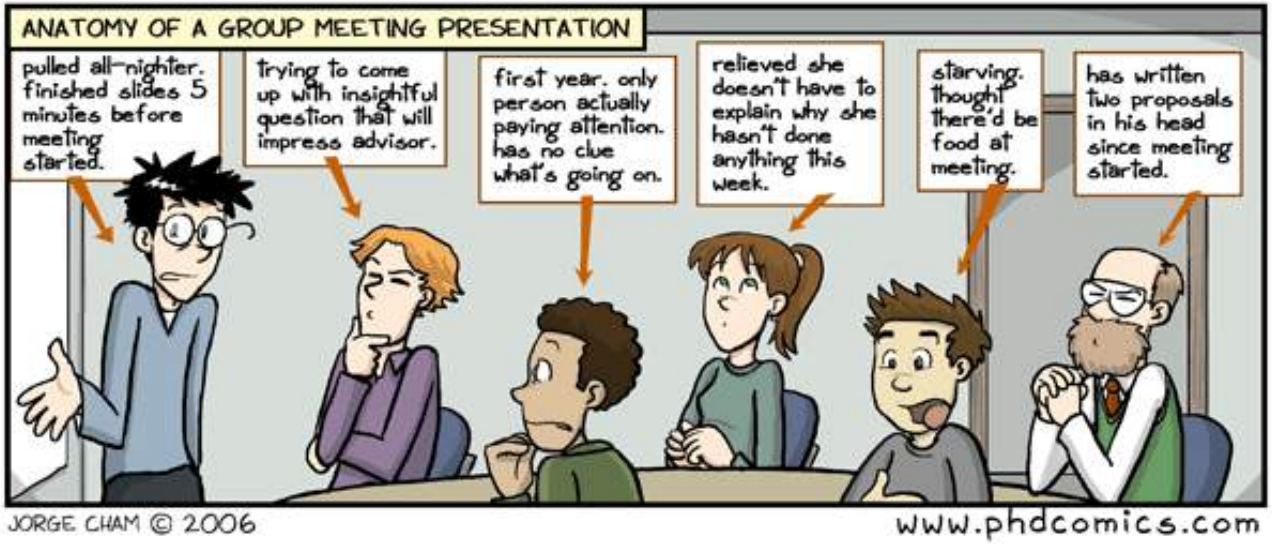
Authors' Note: THIS IS A DYNAMIC PLAN, DO NOT FORGET TO CONCLUDE

How to ?

1.Write scientific papers

2.Make a presentation

3. Publish onlinec



Authors' Note: TOO SMALL BUT IT EXISTS (SLIDE NUMBER)

Slides derived (and augmented) from Serge Abrate* will be noted Thanks to SA

*Serge Abrate
Mechanical Engineering and Energy Processes
Southern Illinois University
Carbondale, Illinois

So, you want to write a paper?

Why?

- You have to (your advisor tells you to …)
- To get credit for your work (get recognition, document your activities,…)

Objectives:

- Get published
- Make sure people find your paper
- Get cited

Thanks to SA

Journal paper VERSUS conference paper

- You should specify the field you are interested in. In computer science, for example, it is very common to publish in conference proceedings due to the faster publishing cycle. However, this is not necessarily true for other fields where conferences might be just gatherings of the community to talk about ongoing research → for us conference is networking only

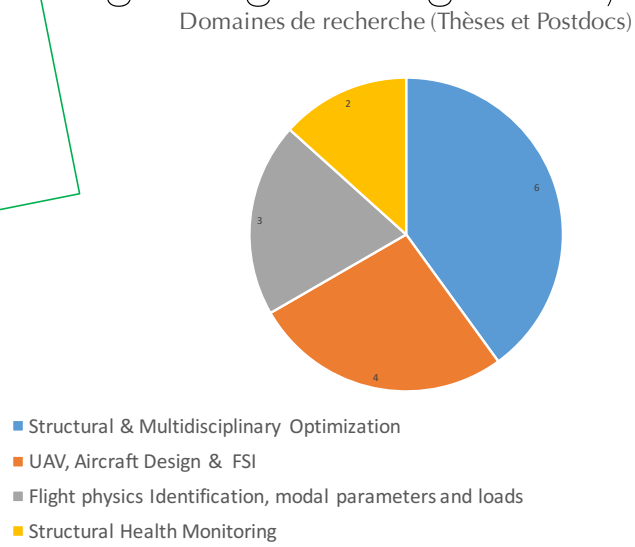
- Journal papers refer to an article that's published in an issue of the journal. The review process for journals often does not have a fixed deadline or schedule: though journals may promise things like "reviews in six weeks", in my experience, this rarely if ever holds true. However, instead of conferences that typically have only accept/reject decisions, journals typically have a rolling review schedule and reviewers can opt to ask the authors for revisions, meaning that there might be multiple review phases (often limited to three, at which stage the paper is rejected/accepted).

Authors' Note:TOO MUCH TEXT HERE JOSEPH

How can I choose a journal?

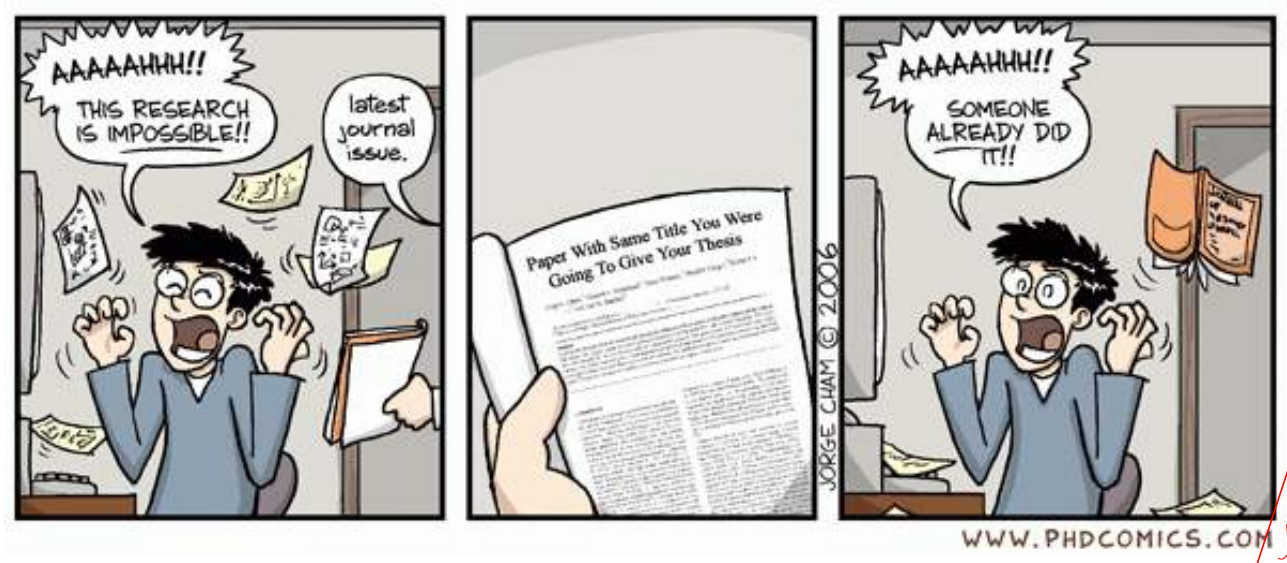
- Mandatory, the journal must have an impact factor
- Either focusing on the thema (applied mathematics, computational solid mechanics, multidisciplinary optimization) or in the application (AIAA journal, Journal of Bridge Engineering etc…)

Do an histogram (or camembert) with your own bibliography !! (or ask your advisor)



Authors' Note: CAN YOU REALLY READ THIS FIGURE?

What?



Be carreful, your work MUST be original !! That's why I really encourage you to read lots of publications thesis....etc ...

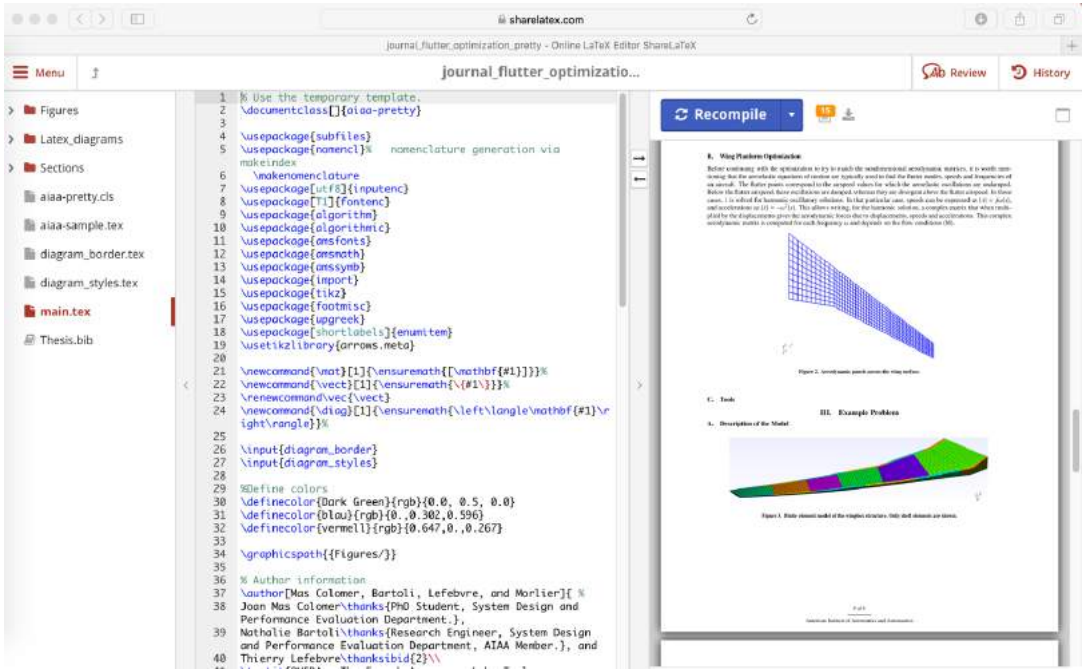
How can I start?

Send me your skeleton (ONLY FIGURES TABLES for RESULTS + the PLAN + title) ALREADY adapted to the journal scope

Use sharelatex or overleaf

Send me the link

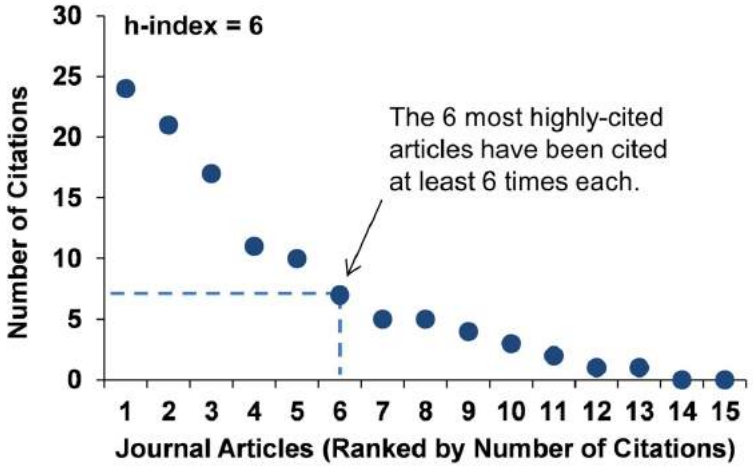
https://fr.sharelatex.com/templates/journals



How can I start (Exploration before Exploitation)

Select a paper of a respected prof (means h-index > 25) and MIMIC THE PLAN

(some sentences can also inspired you !!!!)



BTW, need to add ref in my presentation…

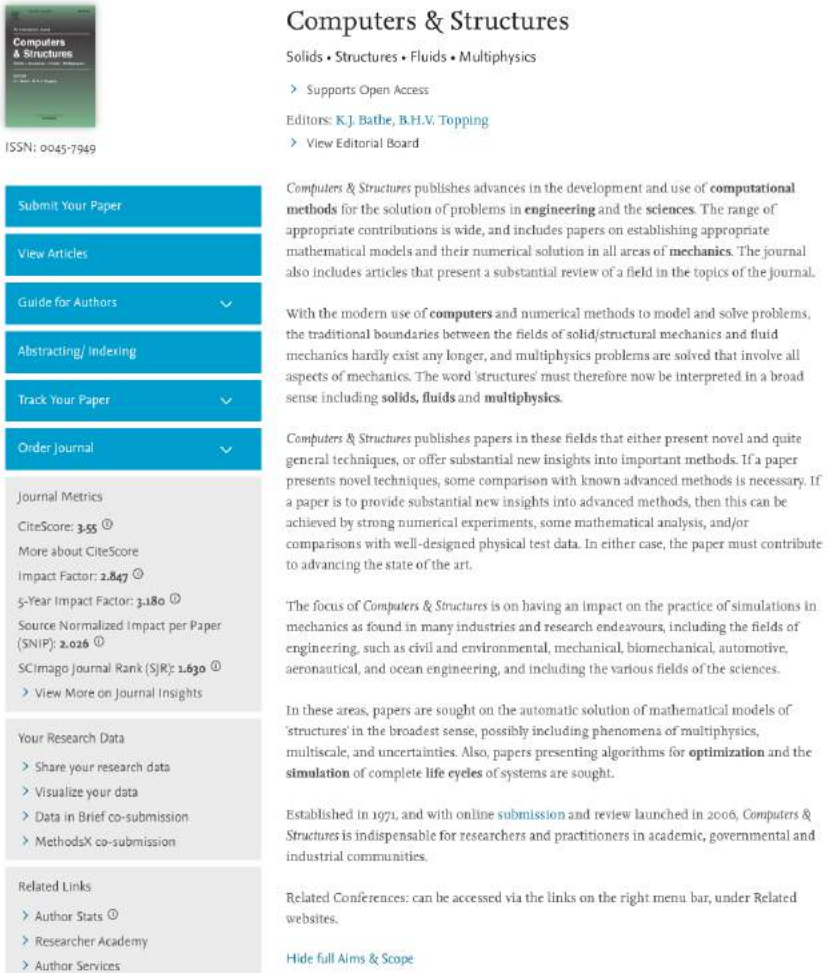
[online ref]:

https://guides.lib.wayne.edu/c.php?g=174971&p=2761081

How can I start (2)

What is journal scope ?

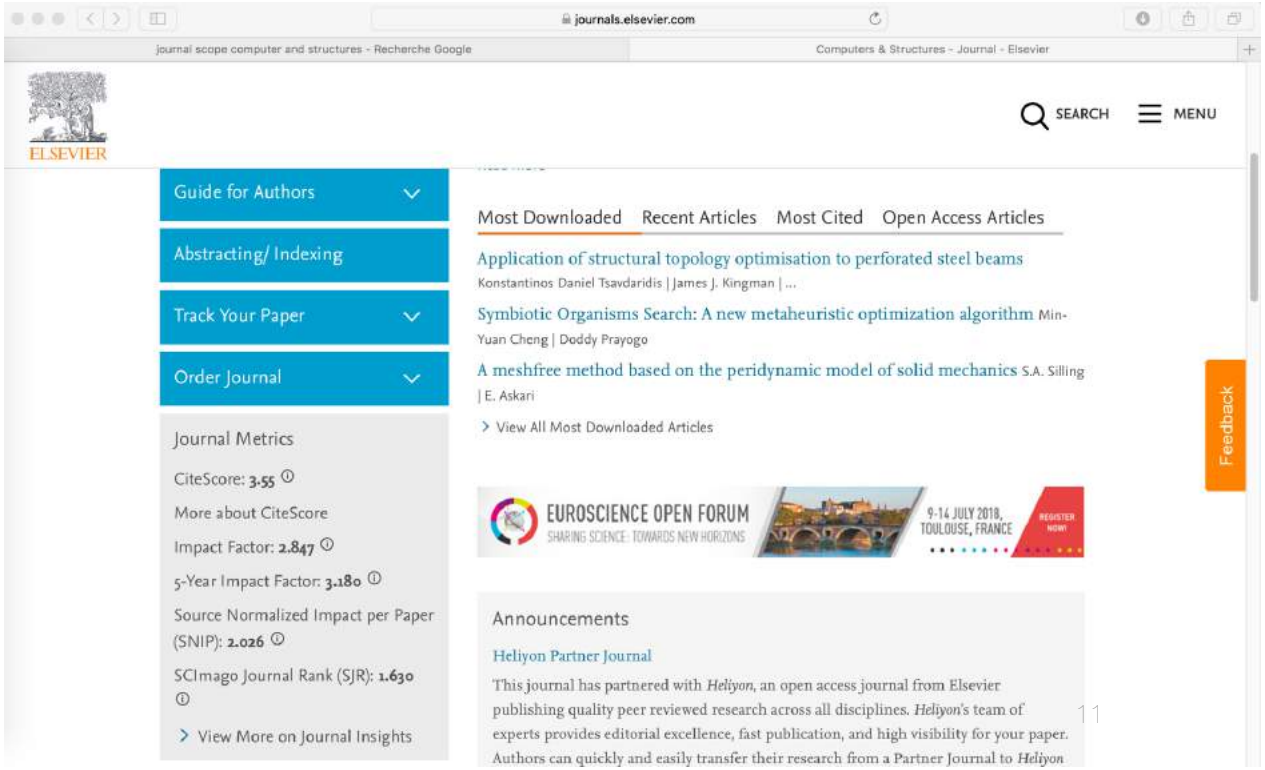
https://www.journals.elsevier.com/computers-and-structures



How can I start (3)

What is journal impact Factor ?

https://www.journals.elsevier.com/computers-and-structures



YOUR RESULTS

NORMALLY researchers publish things that work (ONLY)

But keep in mind (technical note*) things that are not working^^^

Keep also in Mind this is a research paper not a technical note*

If you cite something, someone should be able to read it. If not remove (internal report from industry)

^^^"Scientists are rated by what they finish, not by what they attempt"
Thomas H. Adair (University of Mississippi)

*Authors' Note: A PAPER is a synthesis, not a time history of your research, the essential is needed (use annex, please)

Ask yourself . . .

Think globally (think about the reader), the question is « is it all my results logical*? », for equation "are all the variables described explicitly in the text, in the legend, in the nomenclature?"

Think locally (again think about the reader), the questions are:

« is this figure important, why? » , if not should be in annex. "Do I refer this figure in the text?"

"Are my results reproductible using the input data ?" imagine a reader have no access to your code. Do you provide all the details? If not provide a tutorial/demo with all the codes (see PUBLISH ONLINE)

Try to summarize your results with tables or subfigures. Add crystal clear descriptions/justifications in the text.

https://www.elsevier.com/connect/11-steps-to-structuring-a-science-paper-editors-will-take-seriously

*wrt to your experience, litterature review, past papers, advisor's idea…

Then

- Draft paper (quasi finalized) to be sent to all authors
- PLEASE CHECK YOUR ENGLISH WITH YOUR FRIENDS…

Title

1. The title is the first thing that people see when they search for references
2. It should be short and clearly state what the paper is about
3. Use common terminology, describe general areas of study as well as specific issues.
4. Think of keywords that one might use to find papers like this.
5. Think of a combination of keywords that will make your paper come at the top of the list in a computer search.

Thanks to SA

Four different types of titles

- **Nominal construction**: head with pre- and post-modifiers. Example: Free vibration analysis of shells using a higher order theory.
- **Full sentence construction**. Example: Functionally graded plates behave like homogeneous plates.
- **Compound titles**. Use the interrelationship between the two parts of the title to present the object of study in two different ways: problem–solution, general–specific, topic–method, and major–minor. Example: "Dynamics of structures coupled with elastic media—A review of numerical models and methods".
- **Titles in the form of a question**. Example: Slamming of ships: where are we now?

Thanks to SA

Who is an author?

- Someone who is present at the very beginning and had input in the design of the study
- Made a significant contribution to the work and to the writing of the paper
- Had approval rights on the paper before the paper is submitted

Thanks to SA

Who is not an author?

- A machinist, a technician, a consultant, a secretary, someone who performs a task for a fee
- Someone who provides funding, access to facilities, or is in a position of authority
- Funding sources should be acknowledged in special section at the end of the paper.

Thanks to SA

Abstract

An abstract is a stand-alone statement that briefly conveys the essential information of a paper.

Objectives:

- convince editors and reviewers that this paper is worthy of consideration
- convince potential readers that this paper is worth reading

1. **First sentence:** describe the general area of study
2. **Second sentence**: describe the specific issue under investigation
3. **Third sentence:** describe the approach taken
4. **Fourth sentence**: Mention one or two of the most significant findings

Keep in mind the following: **"Why should anybody want to read any further?"**

Use keywords that will increase the chances of the articles to appear at the top of a search results list

Thanks to SA

Introduction

Objectives:

1. Make sure that everybody knows what this is paper is about (sentences 1 & 2 from abstract)
2. Explain what is already available in the existing literature
3. Point out what is still lacking
4. Explain which specific issue this paper will address, why it is important, and why it cannot be addressed using existing methods
5. Describe the approach taken to address the problem
6. Mention 2 or 3 of the most significant results

¨Why should anybody want to read any further?¨

Thanks to SA

Body of the paper

1. Describe what was done in enough details for somebody else to be able to understand what you did and be able to reproduce it.

2. Expertiments: describe entire apparatus, characteristics of each piece of equipment, what is being measured, what is being deduced from the measurements, estimate accuracy

3. Similar approach for analytical or numerical approaches. Keep number of equations to a minimum. No need for complete derivation.

4. Results: present evidence, draw conclusions, explain significance

Thanks to SA

DO NOT FORGET

1. The formulation

Objective Function		Dimension	Bounds
Mode shape difference minimization	$\min(N - \text{trace}(\text{MAC}([\Phi_r], [\Phi_m])))$	$\mathbb{R}$	
Design Variables			
Skin thicknesses vector	$[t]$	$\mathbb{R}^{10}$	$[0.0889, 26.67]$ mm
Constraints			
Reduced frequency matching	$\|\omega_r - \omega_m\| = 0$	$\mathbb{R}$	
Mass matching	$M_r - M_m = 0$	$\mathbb{R}$	
Generalized masses matching	$\|m_r - m_m\| = 0$	$\mathbb{R}$	

2. Starting point

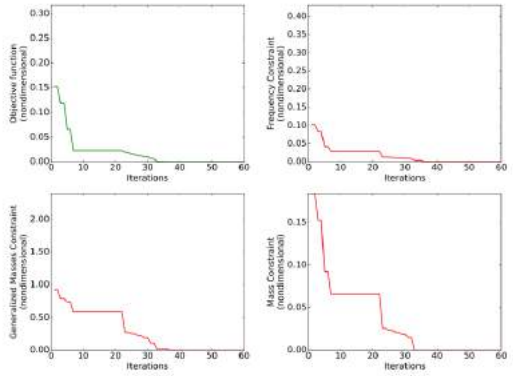
Thickness initialization :Vector of size 10 t1-t10 (meter):

array([
0.01863388, 0.01661411, 0.01273371, 0.01495363, 0.00847329,
0.01743593, 0.02332176, 0.02023447, 0.02068164, 0.0213995])

3. Results

Optimality

Feasibility



DO NOT FORGET (2)

1. Equations needs variables so we need to be described in the …nomenclature
2. Figure in the text should be self explicit and so…the legend very detailed (do not copy the legend in the text)
3. Sometimes compiling several results in a (a,b,c) is good (sometimes not ;))
4. BUT you can put complementary results in annex

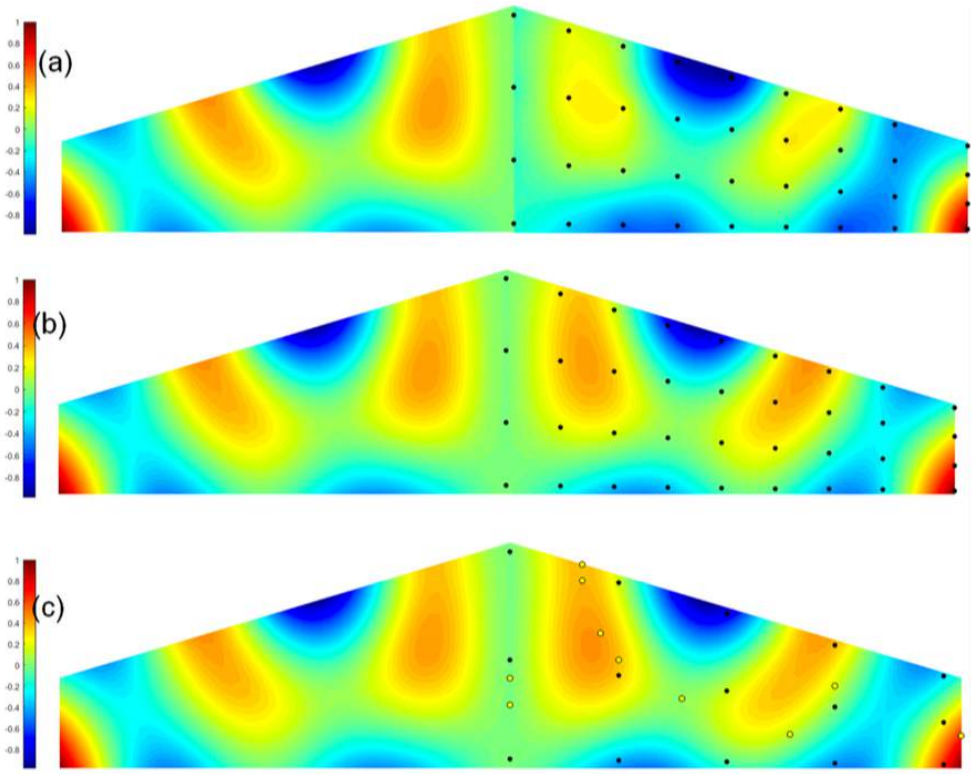


Figure 10. (a) Comparison between HF FEA results (left) and a linear reconstruction with a regular grid of 36 sensors (right), for 9th mode shape. (b) Comparison between HF FEA results (left) and a Kriging reconstruction with a regular grid of 36 sensors (right), for 9th mode shape. (c) Comparison between HF FEA results (left) and EGO-SPO strategy (right) The black dots represent the initial DOE (regular grid, 15 sensors). The yellow ones represent 10 added sensors. This sensor placement strategy allows a reduction of 30.56% of sensors for the entire modal basis.

Authors' Note: colorbar information is missing, but HERE not important for modeshapes

In annex ...

- With a sentence in the text

« The results of the EGO-SPO strategy is illustrated on the figure B1 in appendix B »

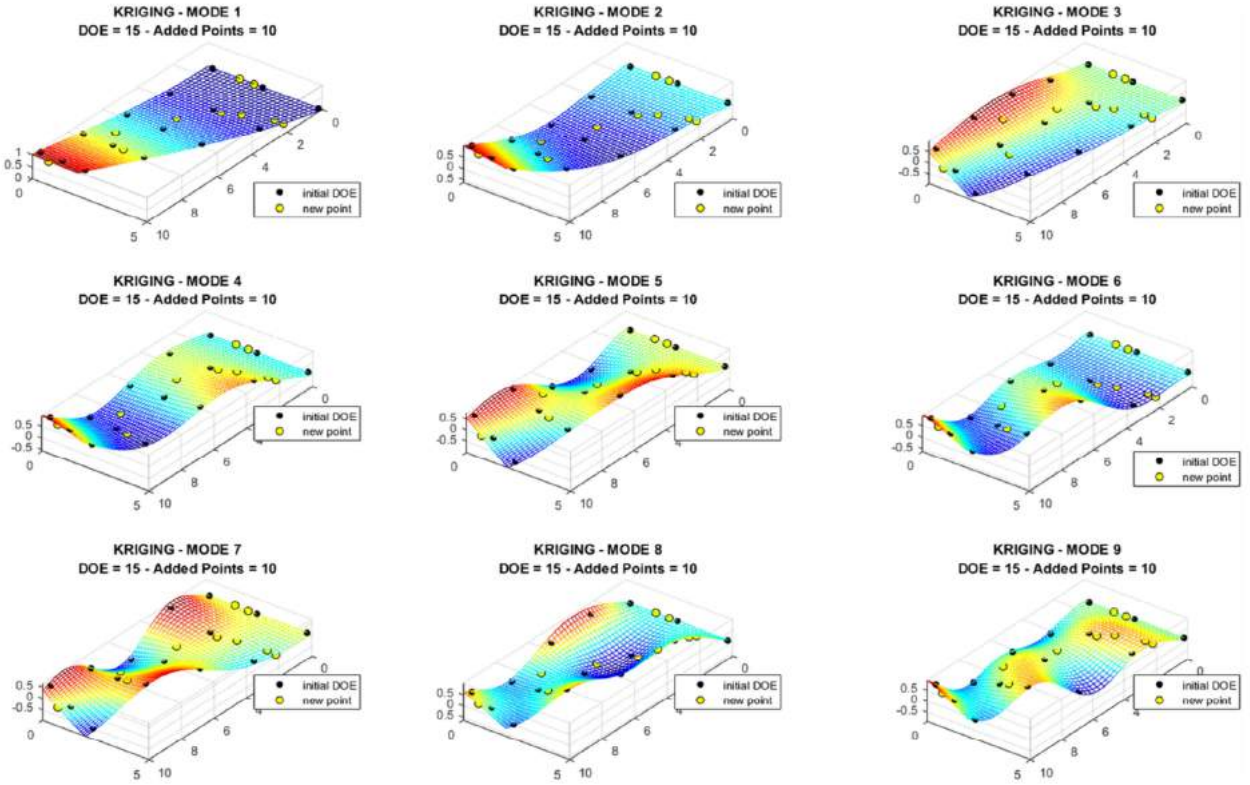


Figure B1. Reconstruction of mode shapes, from 1 to 9. Initial DOE: regular grid with 15 points. Maximal number of sensors: 25. The initial DOE is represented by black dot, the new point chosen by EGO-SPO strategy in yellow.

FIGURES

Think about the main figures that illustrate your point of view (use inkscape eps or png or pdf) , take time to well describe the axis , the variables, the trend, the error ….

Keep editable figure (code), us HQ standard (needed for supplementary materials)

If you put a figure it means it's important so discuss on it !!!

Depending on journal:

Equations should be numbered and

Called in the text

Authors' Note:. ALWAYS ADAPT YOUR PAPER TO THE JOURNAL

Conclusion

- A brief summary of what was done (Introduction announces what we will tell you; body of the paper tells you, conclusion says what we just told you)
- Tell what are the most significant findings (2 or 3)
- What is new here that cannot be found in the existing literature
- Why is it important? Why should anybody care?

Thanks to SA

Figures

1. Pay attention to what the final size of the figure will be. What looks good on a full computer screen may not be acceptable when reduced to 2" x 2".
2. Figures should be self-explanatory. By looking at the figure, one should be able to see everything that you want him to see. The caption has a big role to play in this but if there are different features you want people to see they should be pointed out.
3. Figures should be part of the narrative and not something added afterwards for decoration. They should be mentioned in the text and should be introduced because they have information that cannot be conveyed otherwise.
4. Figures should be numbered consecutively.

Thanks to SA

GENERAL WRITING GUIDELINES

- Write clearly and concisely.
- Avoid long sentences (more than two lines)
- Use an active style (***The impact of the sphere on the structure generated several types of internal damage***) instead of a passive style (***Several types of internal damage were introduced into the structure during the impact by a sphere***)
- Every paragraph should start with a clear statement of the topic.
- Use short and/or simple words:

	Instead of	Write:
1	demonstrate	show
2	Due to the fact that	because
3	In the vast majority of cases	Often,
4	In close proximity to	Close
5	it has long been known that	I'm too lazy to look up the reference

Thanks to SA

Tenses

- Use the present tense in describing published results (Timoshenko's beam theory shows that shear deformation is significant for short beams). The idea is that those results are accepted as facts.
- The results presented in your paper are not yet accepted as fact and were obtained prior to the writing of your paper (displacements were measured using a dial gage).

The writing should be impersonal

Do not use I or we. The article should be about the work and not about the author. Writing "Displacements were measured using a dial gage" is better than "I measured the displacements using a dial gage". The latter introduces the author into the process and invites questions about his competence or gives the impression that he is bragging about everything.

Avoid weasel words

Using "might," "may," and "would" suggests that the author is not sure or that he is trying to avoid making a clear statement. The study should have clear results. If not the work is not ready for publication.

Thanks to SA

Contractions

Never use contractions such as: didn't, can't, haven't…

Copyediting

- typos and spelling errors;
- garbled passages;
- missing tables and figures;
- format inconsistency;
- Language (grammar, syntax, spelling).
- Lists of abbreviations or symbols may be compiled.
- References may be checked for accuracy and consistency.
- Use of capital letters may be standardized.
- Use of units of measure may be checked for appropriateness and consistency.

Thanks to SA

Content editing

- Check the presence of all cited tables, figures, and references. They should be complete and self-explanatory.
- Do equation numbers, figure numbers, table numbers, or references numbers match?
- Are figures and tables in the right places?
- Abstract, introduction, and conclusions must not contain contradictory statements
- Avoid an opening that does not grab your reader (in the title, the abstract, or any other section of the paper)
- Are the facts and details consistent throughout the text?
- Does the information flow cleanly from one idea to the next?
- Are the explanations clear and unambiguous?
- Do the explanations lead readers to the appropriate conclusions?
- Punctuations may be verified to guarantee comprehension.

Thanks to SA

Decrypting a paper...

Title (probably the most important)
, name and * adress
sometimes Keywords are asked

Resume (write at the end) + Nomenclature (compulsory)

Bayesian Adaptive Sampling for Categorical Design Alternatives

José Valenzuela del Río* and Dimitri Mavris †
Georgia Institute of Technology, Atlanta, Georgia, 30332, USA

Real aerospace design problems normally engage not only metric variables but also categorical ones such as materials, beam cross-sections, and airfoils among others. However, the majority of the design tools are tailored for continuous and/or integer variables. This paper develops a new Gaussian process metamodel that leverages trends in typical engineering design objectives that are similar across categories. This work also extends the use of expected improvement (ExI) searches to the previously proposed Gaussian process model to enable more efficient searches in domain spaces that include categorical variables. The proposed Gaussian process model is successfully compared with traditional independent surrogates for each category when modeling a mixed-integer-categorical canonical function with a choice of six categories. Then, the ExI search algorithm is applied to the proposed Gaussian process model to adaptively sample the mixed-integer-categorical canonical function and a rotor hover power consumption.

Nomenclature

b	Number of Rotor Blades
c	Blade Chord
C_Q	Rotor Torque Coefficient
C_T	Rotor Thrust Coefficient
d	Distance Metric
d_h	Hamming Distance
$E[I]$	Expected Improvement
$error$	Standardized Surrogate Error
FM	Rotor Figure of Merit
I	Improvement
k	Dimensionality of Design Space
$\mathbf{N}$	Natural Numbers
$N_{tr,set}$	Number of Points of the Surrogate Training Set
n	Number of Points in the Training Set
$\mathbf{R}$	Kriging Correlation Matrix
R	Rotor Radius
$\Re$	Real Numbers
Re	Reynolds Number
res	Standardized Surrogate Residual
$\hat{s}^2$	Surrogate Mean Squared Error
V	Volume of the Design Space
$\mathbf{x}$	Design Variables
Y	Stochastic Process
$y(\mathbf{x})$	Objective Function
$\hat{y}$	Kriging Predictor
$\boldsymbol{\theta}$	Kriging Hyperparameters
θ_l	Blade Linear Twist
μ	Mean of the Kriging Stochastic Process

*Graduate Student, Department of Aerospace Engineering, 270 Ferst Drive, Atlanta, GA 30332.
†Boeing Professor of Advanced Aerospace Systems Analysis, Department of Aerospace Engineering, 270 Ferst Drive, Atlanta, GA 30332.

Intro

you can check my advices...

thema

Subject

limitations

Classical solutions

Your work (JUSTIFY)

I. Introduction

In recent times, the aerospace industry has searched for efficient designs and optimization techniques that satisfy the more and more demanding system requirements. This search emphasized on an increase in performance and reduction in cost. Much of the work done focuses on continuous techniques. However, real aerospace design problems normally engage not only continuous variables but also discrete-categorical[3] ones such as materials, airfoil sections, beam cross-sections, and manufacturing processes among others.

Discrete variable selection is normally settled in early design stages because their changes are large by nature so that the impact of these choices in the design is large. These decisions could fix a high percentage of the life cycle cost. Variable changes in later stages of the design process could have a great enhancement in the design performance but also in the whole design concept, making changes prohibitive in many cases, specially for categorical variables. Engineers prefer being aware of these desirable changes earlier in the process where the impact of the change is lower; thus, more and more faithful, but also computationally expensive, tools are used in conceptual design. However, the current state-of-the-art design methods provide poor accuracy for a given budget of intense function calls. There is a need for new more efficient techniques that provide: a) more accuracy for a given number of function calls or b) less function calls for a given accuracy.

Many engineering efforts attempt to enable the use of intense codes in early design. These efforts focus on alleviating two limitations stemming from the high computational burden of the codes for concept evaluation and the multi-modality landscapes of typical objectives. The first limitation is the time taken to evaluate design concepts whereas the second one is the number of evaluations needed for the optimization in conceptual design.

Surrogate modeling alleviates the design evaluation time. They consist in constructing cheap approximation models to the objective of a concept that intend to approximate the behavior of the real objective. The most common surrogate models are polynomial response surfaces, Bayesian metamodels, support vector machines (SVM), and artificial neural networks (ANN). They have been widely used as it can be seen in the literature.[1–4]

Gaussian random field metamodels (GRFM), also known as Kriging, have become popular because of their capability of predicting the uncertainty of the prediction while being able to cope with non-linear problems. Much of the efforts in the Bayesian modeling have been devoted to this type of surrogates. These characteristics make Kriging really appealing for engineering design problems. Krige first developed it for mining problems.[5] Sacks et al. were the first ones before many to apply Kriging to computer experiments.[6]

It is not rare that observed trends of objective functions for several categories of the same concept are similar.[7–9] Figure 1 shows one example: the splitting tensile strength for different beams made of different materials experiences similar trends.[9] Thus, some resemblance between behaviors could be taken advantage of. However, current approaches fit independent metamodels for each category with no cross-use of evaluations across categories.

The second limitation is the number of evaluations needed for the optimization. It is tackled by efficient global optimization (EGO) techniques.[10,11] They are smart algorithms that combine two focuses: the global accuracy of the model to assure global search (exploration) and the accuracy of the model in the region of the optimum (exploitation). EGO algorithms are an alternative to traditional design of experiments (DoE) that waste resources in bad performing regions.

The goal of this paper is to build surrogates that leverage similar trends across categories to build more efficient design tools. Their efficiency is compared with the current state-of-the art: independent modeling for each category. Also, the extension of adaptive sampling techniques to deal with these surrogates is presented. Only interpolation techniques are presented in this paper. Similar metamodels but capable of dealing with "noisy" functions are being developed.[12] As previously mentioned, these techniques are developed to build

The basics

Conclude the intro with the plan

(write at the end)

No new stuff here, only the essential of the methodology

Use journal's notation for scalar, vector, matrix etc…

In the next part of the paper the methodology is presented. It is followed by the results and discussion. Finally the conclusions are laid down.

II. Methodology

Firstly Kriging metamodels are reviewed and their performance indicators are defined. Second, the surrogate that takes advantage of similar trends across categories is introduced. Then, the one-objective expected improvement is presented as adaptive sampling criterion and its optimization in a mixed-integer-surrogate domain is explained.

A. Kriging Surrogates

The metamodel chosen in this work is the well-known ordinary Kriging.[11] In this method the observed responses are viewed as if they are from a stochastic process,

$$Y\left(\mathbf{x}^{(i)}\right) = \mu + \epsilon\left(\mathbf{x}^{(i)}\right) \qquad \text{for } i = 1, \ldots n$$

where n is the number of points in the training set and ϵ is the error between the stochastic process and a constant mean μ. $\epsilon(\mathbf{x})$ follows a normal distribution.

The components of the observed responses, $Y\left(\mathbf{x}^{(i)}\right)$, are correlated

$$cor\left[Y\left(\mathbf{x}^{(i)}\right), Y\left(\mathbf{x}^{(l)}\right)\right] \doteq \mathbf{R} \tag{1}$$

where i and l are indexes to point elements in the training set. The matrix $\mathbf{R}$ is the Kriging correlation matrix, chosen here to be based on Gaussian radial basis functions

$$\mathbf{R} = \exp\left(-\sum_{j=1}^{k} \theta_j |x_j^{(i)} - x_j^{(l)}|^2\right) \tag{2}$$

The unknown Kriging hyper-parameters, (θ, μ, σ), are obtained from the maximum likelihood estimation (MLE) of the observed data.[11] The resulting predictor, $\hat{y}$, is

$$\hat{y}(\mathbf{x}) = \hat{\mu} + \psi^T \mathbf{R}^{-1}(\mathbf{y} - \hat{\mu}\mathbf{1}) \tag{3}$$

where

$$\hat{\mu} = \frac{\mathbf{1}'\mathbf{R}^{-1}\mathbf{y}}{\mathbf{1}'\mathbf{R}^{-1}\mathbf{1}}$$

$\mathbf{1}$ is a n-dimensional vector of ones, and ψ is the correlation vector between the point $\mathbf{x}$, where the prediction is pursued, and observed points $\mathbf{x}^{(i)}$ for $i = 1, 2, \ldots, n$

$$\psi = \{cor\left[Y\left(\mathbf{x}^{(1)}\right), Y(\mathbf{x})\right], \ldots cor\left[Y\left(\mathbf{x}^{(n)}\right), Y(\mathbf{x})\right]\}$$

Recap of:

The criteria to compare !!! MANDATORY

1. Performance Indicators

The purpose of a metamodel is to approximate a computational expensive function. Hence, a straight-forward indicator of the metamodel performance is its error. This error is standardized by the typical change in the objective function in its design space, $y^{\star}_{ch}$. One can write the standardized surrogate error as

$$error = \frac{|y(\mathbf{x}) - \hat{y}(\mathbf{x})|}{y^{\star}_{ch}}$$

The Kriging model previously presented is a probabilistic metamodel that does not predict a deterministic value for a design, x, but a probability distribution. In order to measure the accuracy of its probabilistic error, a standardized surrogate residual is employed.[6] It is defined as follows

$$res = \frac{|y(\mathbf{x}) - \hat{y}(\mathbf{x})|}{\hat{s}(\mathbf{x})}$$

Surrogates approximate the objective function in its design space. So, an average of the error and residual of the objective function in the design space is needed. Thus, the performance indicators are the root mean squared (rms) of the surrogate standardized error and residual, given by Eqs. 6 and 7

$$error_{rms} = \sqrt{\frac{1}{V}\int_V \frac{|y(\mathbf{x}) - \hat{y}(\mathbf{x})|^2}{y^{\star 2}_{ch}} d\mathbf{x}} \quad (6)$$

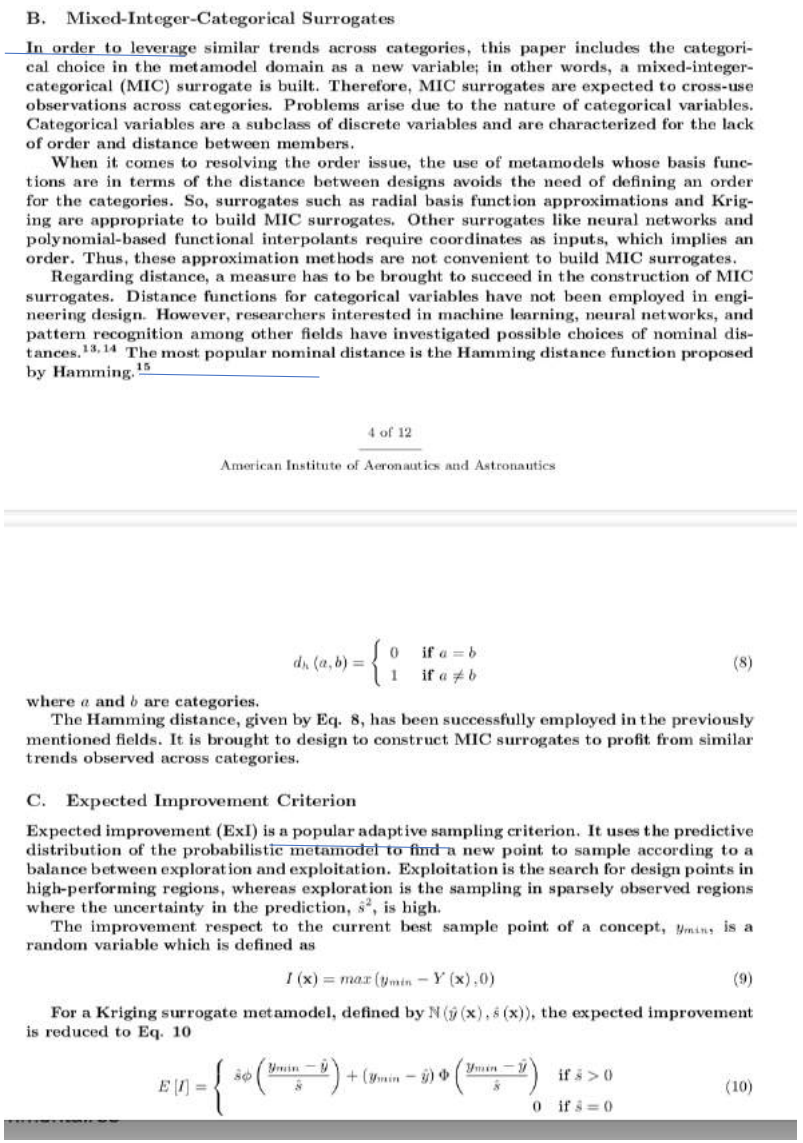
$$res_{rms} = \sqrt{\frac{1}{V}\int_V \frac{|y(\mathbf{x}) - \hat{y}(\mathbf{x})|^2}{\hat{s}^2(\mathbf{x})} d\mathbf{x}} \quad (7)$$

Use standard one, if not justify

Your improvement

Here is the core … of your work

Keep in mind you really need to be pedagogical



B. Mixed-Integer-Categorical Surrogates

In order to leverage similar trends across categories, this paper includes the categorical choice in the metamodel domain as a new variable; in other words, a mixed-integer-categorical (MIC) surrogate is built. Therefore, MIC surrogates are expected to cross-use observations across categories. Problems arise due to the nature of categorical variables. Categorical variables are a subclass of discrete variables and are characterized for the lack of order and distance between members.

When it comes to resolving the order issue, the use of metamodels whose basis functions are in terms of the distance between designs avoids the need of defining an order for the categories. So, surrogates such as radial basis function approximations and Kriging are appropriate to build MIC surrogates. Other surrogates like neural networks and polynomial-based functional interpolants require coordinates as inputs, which implies an order. Thus, these approximation methods are not convenient to build MIC surrogates.

Regarding distance, a measure has to be brought to succeed in the construction of MIC surrogates. Distance functions for categorical variables have not been employed in engineering design. However, researchers interested in machine learning, neural networks, and pattern recognition among other fields have investigated possible choices of nominal distances.[13,14] The most popular nominal distance is the Hamming distance function proposed by Hamming.[15]

$$d_h(a,b) = \begin{cases} 0 & \text{if } a = b \\ 1 & \text{if } a \neq b \end{cases} \tag{8}$$

where a and b are categories.

The Hamming distance, given by Eq. 8, has been successfully employed in the previously mentioned fields. It is brought to design to construct MIC surrogates to profit from similar trends observed across categories.

C. Expected Improvement Criterion

Expected improvement (ExI) is a popular adaptive sampling criterion. It uses the predictive distribution of the probabilistic metamodel to find a new point to sample according to a balance between exploration and exploitation. Exploitation is the search for design points in high-performing regions, whereas exploration is the sampling in sparsely observed regions where the uncertainty in the prediction, $\hat{s}^2$, is high.

The improvement respect to the current best sample point of a concept, y_{min}, is a random variable which is defined as

$$I(\mathbf{x}) = max\left(y_{min} - Y(\mathbf{x}), 0\right) \tag{9}$$

For a Kriging surrogate metamodel, defined by $\mathbb{N}\left(\hat{y}(\mathbf{x}), \hat{s}(\mathbf{x})\right)$, the expected improvement is reduced to Eq. 10

$$E[I] = \begin{cases} \hat{s}\phi\left(\frac{y_{min} - \hat{y}}{\hat{s}}\right) + (y_{min} - \hat{y})\,\Phi\left(\frac{y_{min} - \hat{y}}{\hat{s}}\right) & \text{if } \hat{s} > 0 \\ 0 & \text{if } \hat{s} = 0 \end{cases} \tag{10}$$

Time for R&D

NEED TO prepare

Some nice figures
(it's not so easy to construct a « GOOD VISUALISATION…)

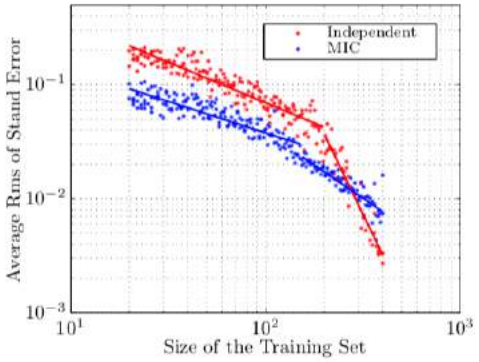


Figure 2. Surrogate Standardized Validation Error. MIC vs Independent Surrogate. Modified Branin Function

III. Results and Discussion

First, MIC surrogates are compared with traditional independent surrogates (one for each category) while approximating a mixed-integer-categorical canonical function defined in Appendix A. It is followed by the visualization of the updates of the adaptive sampling algorithm applied on the same canonical function. Finally, the same update visualization is done when adaptively sampling a rotor hover power consumption.

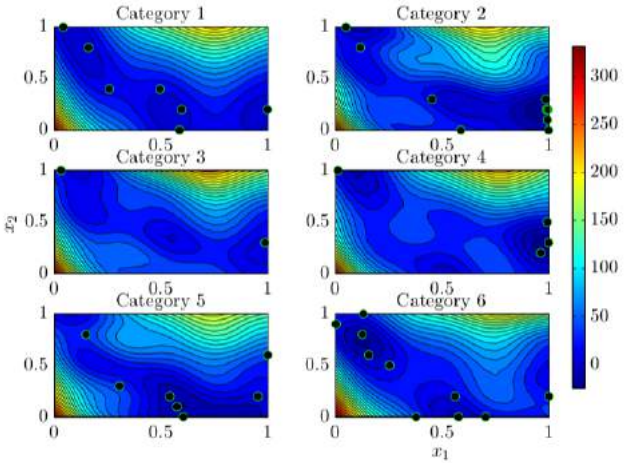


Figure 4. Modified Branin Function. Warm-up Size 54. 40 Updates.

B. Adaptive Sampling on the Modified Branin function

The idea is to run the adaptive sampling technique for 40 updates starting with an initial warm-up sampling plan of 54 points. The adaptive sampling technique is run on the MIC surrogate based on the Hamming distance. The problem chosen is again the modified Branin function explained in Appendix A. The update points are plotted to see if their layout follows the typical EGO optimizer pattern: high density of updates in globally good performing design regions, and low density in globally bad performing design regions.

Figure 4 shows the updates as green circumferences filled with black together with contours for each nominal variable for clarity. Even though the contour plots are filled, it is important to remark that the vertical variable is discrete-quantitative (it can be seen that all the samples are on tenths on the x_2 design input. For more details, see Appendix A).

Figure 4 shows EGO type optimizer's behavior, i.e. samples are concentrated in the globally optimal areas of design (categories 2, 4, 5, and 6 as discussed in Appendix A) and low update concentration in globally bad performing regions.

The Validation

The « supervised ^^^» computer experiment is now working,

Now we can optimize and compare to others methodologies AND/OR Validation with more complex code/experiments

→ need to Highlight the gains/improvements of your methodology

^^^ It is called supervised learning because the process of an algorithm learning from the training dataset can be thought of as a teacher supervising the learning process. We know the correct answers, the algorithm iteratively makes predictions on the training data and is corrected by the teacher. Learning stops when the algorithm achieves an acceptable level of performance.

C. Rotor Model Validation

A simple rotor model is presented in this work to apply MIC surrogates on aerospace design scenarios. The objective function used to validate is the figure of merit, FM, of a rotor helicopter. A low fidelity rotor model is constructed. It includes: Blade Element Momentum (BEM) theory with Prandtl tip losses (for more details, see Leishman's work[7]); characteristic aerodynamic curves are obtained with XFOIL (for more details, see Drela's work[16]); and rigid blades.

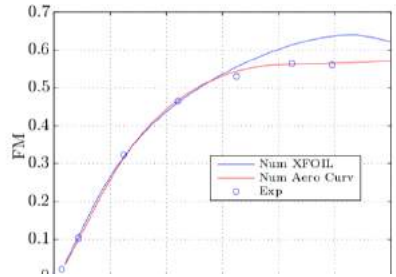
Knight and Hefner provide helicopter rotor experimental data.[17] Their work is utilized for validation. A two bladed-rotor and an airfoil NACA 0015 are chosen to validate the low fidelity model developed in this paper. The chord is set constant throughout the span and equal to 2 inches and no twist is present. Blades are clamped in the inner end and collective pitch is allowed for trimming purposes. The rotor blade Reynolds number is 242000. The average rotational speed is 960 revolutions per minute (100.53 rad per second).

The low fidelity model is run for two characteristic aerodynamic curves from different sources:

XFOIL Aerodynamic Curves. Characteristic aerodynamic curves are obtained with the help of XFOIL. The code is run with the following parameters: $Re = 242000$ and $M = 0$.

Aerodynamic Curves from Knight and Hefner.[17] Characteristic aerodynamic curves are taken from Table 6 of Knight and Hefner's work.[17] This table contains experimental aerodynamic curves for airfoil NACA 0015.

Comparison between the experimental and numerical data serves as the validation procedure. Figures of merit (FM versus C_T) is shown in Figure 5. It could be seen that the low fidelity model that uses experimental aerodynamic data (in Figure 5 the label "Num Aero Curv") approaches quite well to the experimental data. The reason for the poorer results for the XFOIL model is its basic aerodynamic model as opposed to the experimental aerodynamic case, where the characteristic aerodynamic curves are obtained by the authors exclusively for the given test case.[17]



The appendix

If the core of the paper is too long…
use appendix for detailed formulation and/or Complementary results

Appendix

A. Modified Branin Function

The Branin function is a two-variable function given by Equation 14

$$f(X_1, X_2) = \left(X_2 - \frac{5.1}{4\pi^2}X_2 + \frac{5}{\pi}X_1 - 6\right)^2 + \left[\left(1 - \frac{1}{8\pi}\right) cos(X_1) + 1\right] + 5X_1 \quad (14)$$

where the domain is $X_1 \in [-5, 10]$ and $X_2 \in [0, 15]$.

First of all the original function is made dimensionless so that non-bias is produced when the Kriging surrogate is fitted. The new independent variables are

$$x_1 = \frac{X_1 + 5}{15} \qquad x_2 = \frac{X_2}{15} \quad (15)$$

The intention is to transform it to a test function on a mixed-integer-categorical design space, called modified Branin function. The purpose of this function is to test MIC surrogates. They are intended for functions with similar trends across categories, so the modality of all modified Branin function categories must be similar to the original Branin function.

The method proposed to obtain modified Branin function consists in calculating the Fourier series of the original Branin function and alter randomly the 9 first Fourier coefficients. Dym and McKean,[18] among many others, provide information about the Fourier transform.

The amplitudes and phases of the 9 highest modes of the Fourier transform are randomly modified by two normal distributions according to the following formula:

$$\hat{f}\prime(n_1, n_2) = \hat{f}(n_1, n_2) \exp\{i \cdot rnd_1\} (1 + 0.05 \cdot rnd_2) \quad (16)$$

where $\hat{f}$ and $\hat{f}\prime$ are the Fourier coefficient of the original Branin function and modified Branin function category respectively; n_i is the Fourier frequency in the i coordinate dimension; and rnd_i is a standardized normally distributed random number $\mathcal{N}(\mu = 0, \sigma^2 = 1)$. The second factor of the right hand side, $\exp\{i \cdot rnd_1\}$, is a change of phase of $\frac{rnd_1}{2\pi}$ radians in the Fourier coefficient, whereas the last factor $(1 + 0.05 \cdot rnd_2)$ represents a change of

It's time to conclude (briefly, (write at the end))

also to do some acknowledments

and add references (using bibtex and scholar) using journal's guidelines

IV. Conclusion

MIC surrogates have been developed to apply similar trends across categories. MIC surrogates have been tested on a noise-free functions like the modified Branin function and on a simple model of a rotor. Results show evidence that MIC surrogates are more efficient than traditional independent surrogates in the low range of training set sizes, i.e. the cross-use of observations is effective in this range of training set sizes. However, traditional independent surrogates gain performance respect to the MIC ones as the training set becomes larger. In this large range, high frequency information for each category is available. This high frequency features are different for each category so the cross-use of observations across categories, done by MIC, is no longer efficient.

An adaptive sampling algorithm is applied on the MIC surrogate to search for good designs of the modified Branin function and the rotor hover power consumption. In both cases the majority of the updates are in the globally best-performing areas, which is a typical EGO behavior.

Acknowledgments

This work was supported in part by Aerospace Systems Design Laboratory, the bank "Caja Madrid", and the Center of Excellence for Rotorcraft Technology at the Georgia Institute of Technology.

References

[1]Simpson, T. W., Poplinski, J. D., Koch, P. N., and Allen, J. K., "Metamodels for Computer-ased Engineering Design: Survey and recommendations," *Engineering With Computers*, Vol. 17, o. 2, July 2001, pp. 129–150.

[2]Jin, R., Chen, W., and Simpson, T. W., "Comparative Studies Of Metamodeling Techniques nder Multiple Modeling Criteria," *Structural and Multidisciplinary Optimization*, Vol. 23, No. 1, ec. 2001, pp. 1–13.

[3]Simpson, T. W., Booker, A. J., Ghosh, D., Giunta, A. A., Koch, P. N., and Yang, R. J., Approximation Methods in Multidisciplinary Analysis and Optimization: A Panel Discussion," *tructural and Multidisciplinary Optimization*, Vol. 27, No. 5, June 2004, pp. 302–313.

[4]Keane, A. and Nair, P., *Computational Approaches for Aerospace Design: The Pursuit of Excel-nce*, John Wiley & Sons, Chichester, UK, Aug. 2005.

[5]Krige, D. G., "Statistical Approach to Some Basic Mine Valuation Problems on Witwater-and," *Journal of Institute of Mine Surveyors of South Africa*, Vol. 7, No. 4, 1953, pp. 145–154.

[6]Sacks, J., "Design and Analysis of Computer Experiments," *Statistical Science*, Vol. 4, No. 4, ov. 1989, pp. 409–423.

[7]Leishman, J. G., *Principles of Helicopter Aerodynamics*, Cambridge University Press, New ork, NY, 2006.

[8]Raymer, D. P., *Aircraft Design: A Conceptual Approach*, American Institute of Aeronautics nd Astronautics, Washington D.C., USA, 4th ed., 2006.

[9]Planas, J., Elices, M., Guinea, G., Gmez, F., Cendn, D., and Arbilla, I., "Generalizations and Specializations of Cohesive Crack Models," *Engineering Fracture Mechanics*, Vol. 70, No. 14, Sept. 2003, pp. 1759–1776.

How to ?

1.Write scientific papers

2.Make a presentation

3.Publish online

Start from scratch…

Think about the audience, try to « Tell a story »
https://hbr.org/2012/10/structure-your-presentation-li

Give the big picture at the begining then focus …

But in a conference ALWAYS demonstrate your scientific skills. It means….you REALLY NEED TO make a focus on:

- A brand new algorithm
- A tricky equation
- An original numerical implementation etc…

Bibliography ONLY (10')

1. Title + tutors + 1 figure to illustrate 1 slide

2. Introduction slides presenting the subject (Topology Optimization, Surrogate, aeroelasticity, …) + well known references (SIMP [1], GPML [2], Flutter [3], …) 2 slides max

3. Your subject, the big picture of what you understood right now … 2 slides max with references

4. A focus on an adapted methodology with references and what are the current results (Figures from one or two papers max) + your work if already started 4 slides max

5. Final thoughts (Conclusion and Future works) 1 slide

6. The pdf/pptx should be uploaded on slack and by email to tutors 1 day before

In Progress

RESPECT THE TIME OF THE PRESENTATION (20')

- Introduction: What was the original question?
- Methods: How did the researchers try to answer it? (state of the art)
- Results: What did the previous researchers find (PROs/CONs)? 5'
- Your new method (inspired from?)

your implementation (framework, computational efficiency …)5'

- Discussion about your preliminary results (define before the test case(s): what all these results mean?
- Open questions (implementation issues, futur works)10'

Please send me the draft pdf one day before for a quick review…or come to discuss with me before...

Final

Respect the time of the presentation (20')

Repeat (but not too much)

Think about the main figures that illustrate your point of view (use inkscape eps or png or pdf) , take time to well describe the axis , the variables, the trend, the error ….

If you put a figure it means it's important so discuss on it !!!

Idem for table or equations

Authors' Note:. ALWAYS ADAPT YOUR PRESENTATION TO THE AUDIENCE

SOME ADVICES

for complex equation, you can use colors

Gradient of the function of interest

The function of interest (i) depends uniquely on the design variables (x), but it can be expressed as a function of both the design variables and the state variables. For further clarity, quantities related to aerodynamics are represented in red, whereas the green color is used for structures. These state variables are separated into aerodynamic state variables (w), which may represent doublet intensities or pressure values, and structure state variables (u), which generally represent displacements. These state variables depend implicitly on the design variables through the solution of the aerodynamic and structure residuals ($A(x, w, u)$ and $S(x, w, u)$ respectively):

$$i(x) = I(x, w(x), u(x)) \tag{4.8}$$

The total derivative (gradient) of i can be expressed as:

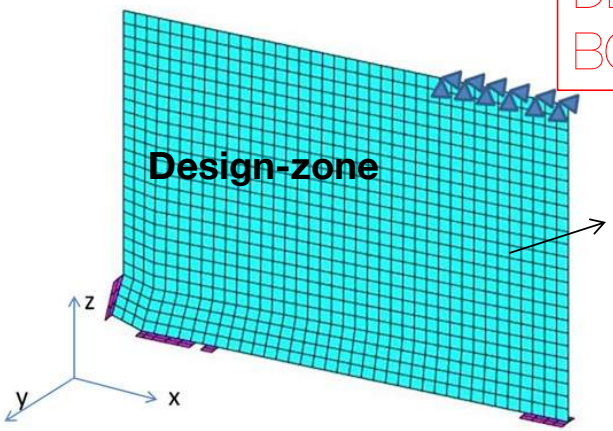
$$\frac{di}{dx} = \frac{\partial I}{\partial x} + \begin{bmatrix} \frac{\partial I}{\partial w} & \frac{\partial I}{\partial u} \end{bmatrix} \begin{bmatrix} \frac{dw}{dx} \\ \frac{du}{dx} \end{bmatrix} \tag{4.9}$$

Both aerodynamic and structure residuals can be expressed as a function of the design variables and the state variables. When the coupling equations are satisfied, the residuals are equal to zero and the state variables which satisfy this condition depend on the design variables uniquely. In that case, $u(x)$ and $w(x)$ express the set of state variables which satisfy the residual equations for a given set of design variables:

$$a(x) = A(x, w(x), u(x)) = 0 \tag{4.10}$$

SOME ADVICES 2

Comparing 2 methods (or more)



Authors' Note: OK I KNOW THE DESIGN ZONE (x) BUT THE BCS AND THE LOAD ??

$$E_{el}(x) = E_{min} + (E_{max} - E_{min})x^p$$

$$v_{el}(x) = x\ V_{el}$$

$$E_{max} = 210000\ Mpa$$

$$E_{min} = \frac{E_{max}}{100} = 2100\ Mpa$$

$$\nu = 0.3\ , p = 3$$

Authors' Note: THIS GREEN IS NOT GOOD. ALWAYS THINK TO THE AUDIENCE

Engine performance driven topology optimization

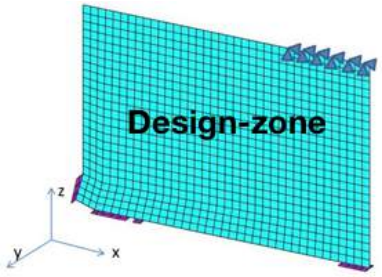
$$\begin{cases} min_x \Delta TSFC(x) \\ 0 \le x \le 1 \\ \dfrac{V(x)}{V_0} \le volfrac \\ [\tilde{K}(x)]\{U(x)\} = \{\tilde{F}\} \end{cases}$$

Authors' Note: Do not forget the stopping criteria or a tolerance…

Compliance Driven topology optimization

$$\begin{cases} min_x \{U(x)\}^T [K_D] \{U(x)\} \\ 0 \le x \le 1 \\ \dfrac{V(x)}{V_0} \le volfrac \\ [\tilde{K}(x)]\{U(x)\} = \{\tilde{F}\} \end{cases}$$

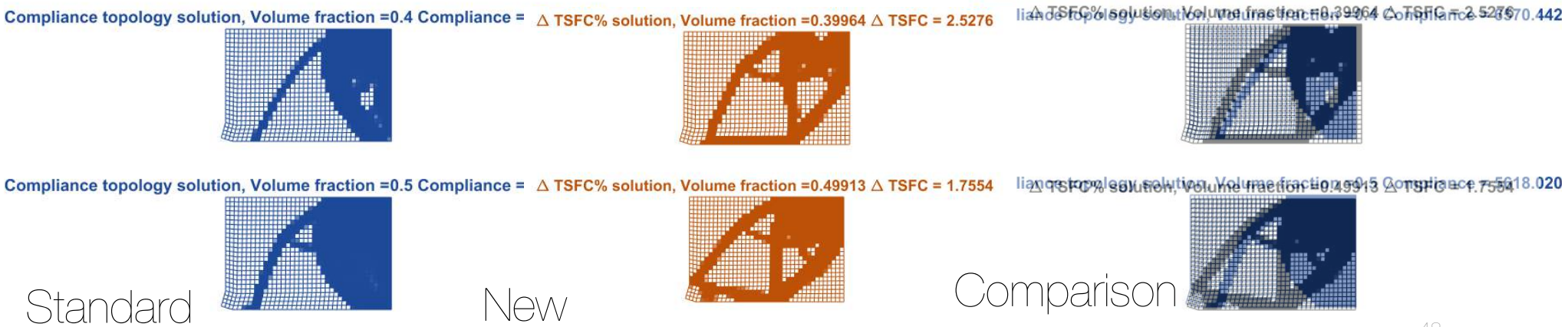
VISUALISE CRITERIA FOR BENCHMARKING (here DIFFERENCE)



Authors' Note:RECAP OF THE CONTEXT HERE

Authors' Note:USE ANIMATION TO COMPARE

(but in general AVOID animation)



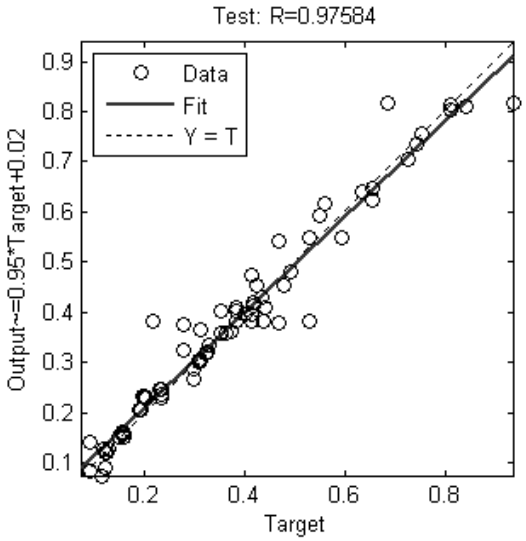
Standard

New

Comparison

CONCLUDE USING SIMPLE GRAPH

- In surrogate modeling can be the predict value (x axis) versus the true value (y axis)
- Use standard criteria (R^2, RMSE …) to illustrate your point of view



How to ?

1.Write scientific papers

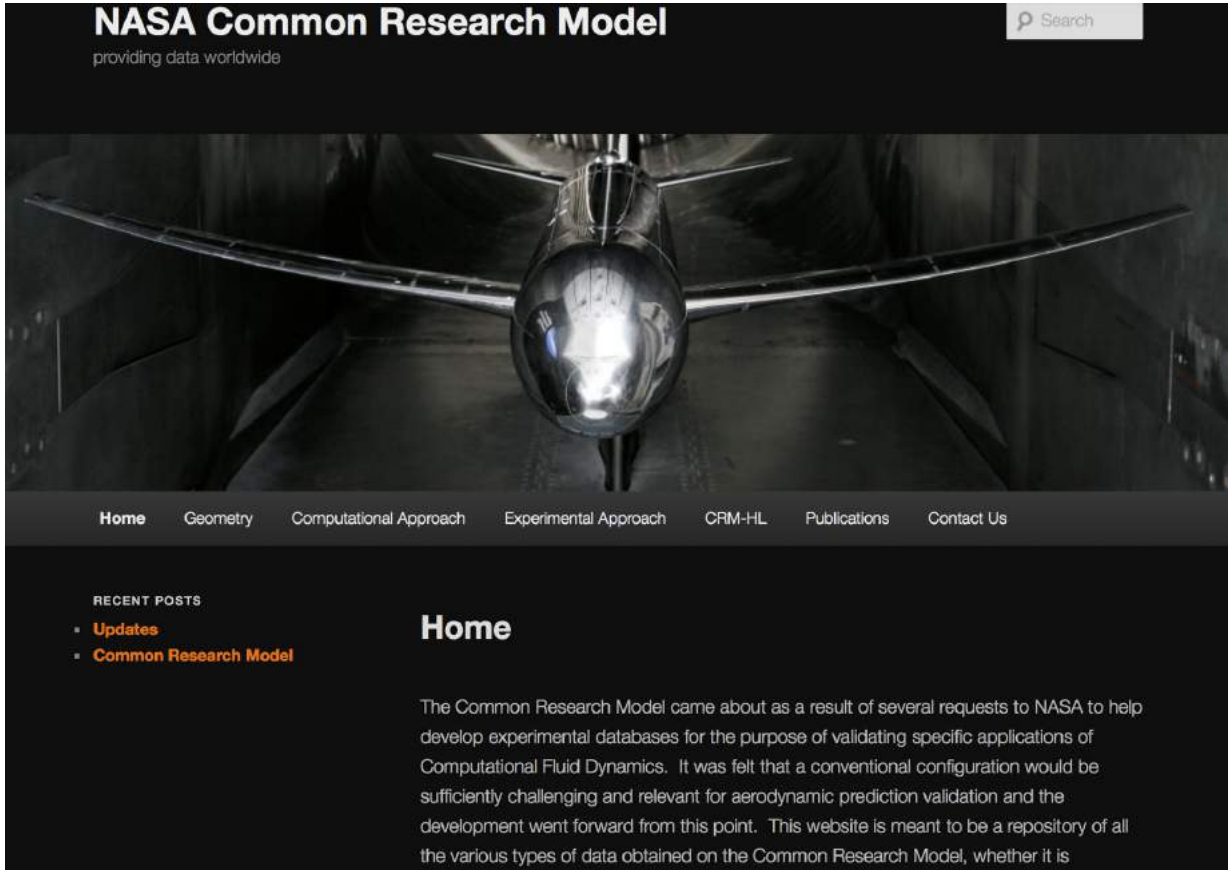
2.Make a presentation

3.Publish online

WHAT IS Reproducible paper ??

Slide Sources:
Victoria Stodden CompareML: Structuring Machine Learning Research in Data Driven Science
Charles Sutton, You and Your Code, Univ. of Edinburgh
Arnaud Legrand Reproducible Research: Where to Begin With?

A (Very) Good Example from … NASA



- Round Robin Test (Test inter Laboratoire en sciences experimentales)
- http://sem.org/dic-challenge/
- http://www.garteur.org

MDOlab popularity increases

Home > Publications > AIAA Journal > Volume 53, Issue 4 > Aerodynamic Shape Optimization Investigations of the Common Research Model Wing Benchmark

Previous Article | VOLUME 53, ISSUE 4 (APRIL) | Next Article

Add to Favorites | Email | Download to Citation Manager | Track Citations

Full-text | PDF | PDF Plus (3,157 KB) | Supplemental Material | Cited By

Zhoujie Lyu, Gaetan K. W. Kenway, and Joaquim R. R. A. Martins. "Aerodynamic Shape Optimization Investigations of the Common Research Model Wing Benchmark", AIAA Journal, Vol. 53, No. 4 (2015), pp. 968–985.
https://doi.org/10.2514/1.J053318

Aerodynamic Shape Optimization Investigations of the Common Research Model Wing Benchmark

Zhoujie Lyu*, Gaetan K. W. Kenway†, and Joaquim R. R. A. Martins‡
Department of Aerospace Engineering, University of Michigan, Ann Arbor, Michigan 48109

*Ph.D. Candidate, Department of Aerospace Engineering. Student Member AIAA.

†Postdoctoral Research Fellow, Department of Aerospace Engineering. Member AIAA.

‡Associate Professor, Department of Aerospace Engineering. Associate Fellow AIAA.

SUBSCRIBE

Online
Member: $140.00
Non-member: $2,425.00

Buy/Renew

RELATED PUBLICATIONS

Google Scholar

Search for other articles
By author
Zhoujie Lyu

Acknowledgements The authors are grateful for support from the National Science Foundation Graduate Research Fellowship under Grant No. DGE-1256260 and from the AFOSR MURI on multi-information sources of multi-physics systems under Award Number FA9550-15-1-0038, program manager Jean-Luc Cambier. The authors would like to thank Shamsheer Chauhan for contributing his figures from the MDO course project, as well as Joseph Morlier and Nathalie Bartoli for their support in the ISAE-SUPAERO course.

Structural and Multidisciplinary Optimization
https://doi.org/10.1007/s00158-018-1912-8

EDUCATIONAL ARTICLE

Open-source coupled aerostructural optimization using Python

John P. Jasa[1] · John T. Hwang[2] · Joaquim R. R. A. Martins[1]

Received: 2 August 2017 / Revised: 28 November 2017 / Accepted: 15 January 2018

Abstract
To teach multidisciplinary design optimization (MDO) to students effectively, it is useful to have accessible software that runs quickly, allowing hands-on exploration of coupled systems and optimization methods. Open-source software exists for low-fidelity aerodynamic or structural analysis, but there is no existing software for fast tightly coupled aerostructural analysis and design optimization. To address this need, we present OpenAeroStruct, an open-source low-fidelity aerostructural analysis and optimization tool developed in NASA's OpenMDAO framework. It uses the coupled adjoint method to compute the derivatives required for efficient gradient-based optimization. OpenAeroStruct combines a vortex lattice method and 1-D finite-element analysis to model lifting surfaces, such as aircraft wings and tails, and uses the coupled-adjoint method to compute the aerostructural derivatives. We use the Breguet range equation to compute the fuel burn as a function of structural weight and aerodynamic performance. OpenAeroStruct has proved effective both as an educational tool and as a benchmark for researching new MDO methods. There is much more potential to be exploited as the research community continues to develop and use this tool.

Keywords Aerostructural design optimization · Wing design · Multidisciplinary design optimization · Project-based learning · Python

1 Summary

In this paper, we discuss OpenAeroStruct,[1] an open-source coupled aerostructural analysis and design optimization tool. OpenAeroStruct couples the vortex-lattice method (VLM) and finite-element analysis (FEA) using six degree-of-freedom (DOF) spatial beam elements with axial, bending, and torsional stiffness. It is mostly implemented in Python, but some of the more intensive computations use Fortran.

[1] https://github.com/mdolab/openaerostruct

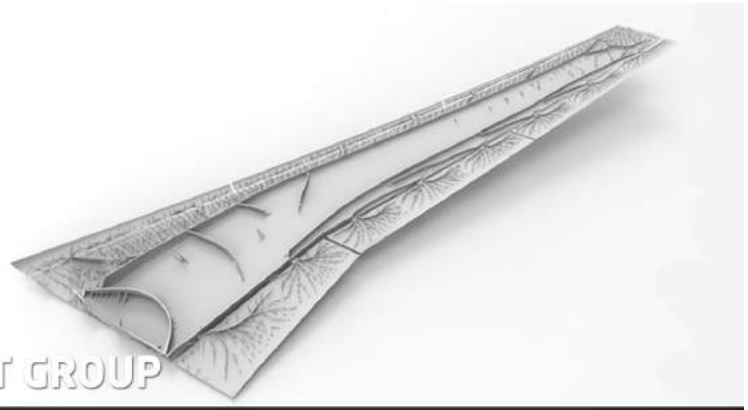
✉ John P. Jasa
johnjasa@umich.edu
John T. Hwang
john.hwang@epeerless.com
Joaquim R. R. A. Martins
jrram@umich.edu

OpenAeroStruct is developed within the OpenMDAO framework (Heath and Gray 2012), a NASA-developed open-source software framework for multidisciplinary design optimization (MDO). OpenMDAO facilitates derivative computation for gradient-based optimization using the modular analysis and unified derivatives (MAUD) architecture (Hwang and Martins 2018), which unifies the adjoint method with the chain rule and all other methods for computing discrete derivatives (Martins and Hwang 2013). OpenAeroStruct computes derivatives for the aerostructural system using the coupled adjoint method (Martins et al. 2005; Kenway et al. 2014). The aerodynamic forces and structural displacements are transferred between disciplines in a consistent and conservative manner. This process is simplified because the aerodynamic and structural meshes have the same spanwise discretization, so no interpolation is necessary to transfer the loads or displacements. A variety of solvers can be used to converge the coupled aerostructural system, including block Gauss–Seidel, GMRES, or LU decomposition for the lin-

Another nice example

TOPOPT

ABOUT US | PROJECTS | APPS/ SOFTWARE | PUBLICATIONS



TOPOPT GROUP

The TopOpt group at DTU Mechanical Engineering is world leading within development and applications of density based topology optimizatior
TopOpt is an acronym for Topology Optimization and the group is a joined research effort between the departments of DTU Mechanical Engine
Compute with the aim of promoting theoretical extensions and practical applications of the topology optimization method. The group is involved
multidisciplinary research projects sponsored from national and international sources.

topopt / TopOpt_in_PETSc

Watch 13 | Star 42 | Fork 20

Code | Issues 1 | Pull requests 0 | Projects 0 | Wiki | Insights

http://www.topopt.dtu.dk/PETSc

36 commits | 1 branch | 0 releases | 2 contributors

Branch: master | New pull request | Create new file | Upload files | Find file | Clone or download

Latest commit 4cc931e on 11 Jan

2 months ago
nality 3 years ago
2 months ago
3 years ago
3 years ago
3 years ago
2 years ago
3 years ago
2 months ago
4 years ago
10 months ago

ing 88 lines of code

nline: 20 November 2010

el programming language that allows
erous scientific problems with a min-
. An example is Sigmund's 99 line
code (Sigmund 2001). The 99 line
educational purposes and serves as
le to topology optimization for stu-
to the field. The use of MATLAB,
tax, excellent debugging tools, and
dling opportunities, allows the user
al and mathematical background of
m without being distracted by tech-
issues. Other examples of simple
to provide insight in finite element
ptimization include a finite element
elliptic problems with mixed bound-
uctured grids (Alberty et al. 1999), a
ms in linear elasticity (Alberty et al.
mization code for compliant mecha-
t conduction problems (Bendsøe and
for Pareto-optimal tracing in topol-
sh 2010), a discrete level-set topol-
(Challis 2010), and a Scilab code for
ization problems based on the level
99).
erformance programming languages
an, MATLAB is generally perceived
comes to computational power. This
by (1) the fact that many users apply

LETTER

doi:10.1038/nature23911

Giga-voxel computational morphogenesis for structural design

Niels Aage[1,*], Erik Andreassen[1], Boyan S. Lazarov[1] & Ole Sigmund[1]

In the design of industrial products ranging from hearing aids to automobiles and aeroplanes, material is distributed so as to maximize the performance and minimize the cost. Historically, human intuition and insight have driven the evolution of mechanical design, recently assisted by computer-aided design approaches. The computer-aided approach known as topology optimization enables unrestricted design freedom and shows great promise with regard to weight savings, but its applicability has so far been limited to the design of single components or simple structures, owing to the resolution limits of current optimization methods[1,2]. Here we report a computational morphogenesis tool, implemented on a supercomputer, that produces designs with giga-voxel resolution—more than two orders of magnitude higher than previously reported. Such resolution provides insights into the optimal distribution of material within a structure that were hitherto unachievable owing to the challenges of scaling up existing modelling and optimization frameworks. As an example, we apply the tool to the design of the internal structure of a full-scale aeroplane wing. The optimized full-wing design has unprecedented structural detail at length scales ranging from tens of metres to millimetres and, intriguingly, shows remarkable similarity to naturally occurring bone structures in, for example, bird beaks. We estimate that our optimized design corresponds to a reduction in mass of 2–5 per cent compared to currently used aeroplane wing designs, which translates into a reduction in fuel consumption of about 40–200 tonnes per year per aeroplane. Our morphogenesis process is generally applicable, not only to mechanical design, but also to flow systems[3], antennas[4], nano-optics[5] and micro-systems[6,7].

Computational morphogenesis is used in engineering to determine the best possible shapes and material distributions for prescribed structural objectives. A very common goal is to minimize structural weight, subject to constraints on deflections and mechanical stresses. Similar goals are drivers of animal and plant evolution. For plants, the optimal ratio of loading capacity to weight ensures efficient use of limited resources; for animals, it minimizes energy consumption for walking and running. Whereas efficient structures in nature generally result from slow genetic evolution, in engineering fast solutions that also take manufacturing limitations into account are necessary. Topology optimization[1,2] works by redistributing material within a predetermined design domain, not unlike natural bone-growth processes. Here, the design domain is defined as the geometric volume in which material can be distributed, such as the space above the building lot for a high-rise building, or the internal part of a car, less the space reserved for passengers, the engine and so on. Through an iterative, deterministic process that involves modelling of the physical system, gradient computations and mathematical programming-based design updates, structural material is gradually redistributed towards the optimal design (Extended Data Fig. 1).

Traditional stiffness-based topology optimization of components is well developed and used routinely in all major mechanical engineering industries, including the automotive[8] and aerospace[9] industries. In the automotive industry, this optimization typically results in weight savings of 20%–40% on structural parts and reduced development times compared to designs obtained using intuition or trial and error by skilled engineers, and eliminates the need to build prototypes. Despite its successes, the applicability of the topology optimization approach is still limited to the design of components or smaller structures. The main obstacle in applying it to large structures is resolution. Just as the visual quality of a television screen is limited by the number of pixels, the geometric quality and capability of the topology optimization process is limited by the number of voxels (three-dimensional equivalent of pixels) that are used to parameterize the design problem. Current state-of-the-art implementations limit voxel numbers to a few million and hence make their application to the detailed design of high-rise buildings, oil rigs or large aeroplanes impossible. This provokes the question of whether giga-voxel-resolution computational morphogenesis would lead to radical design changes. If so, we expect these new designs to result in substantial weight savings and reduced environmental impact.

We investigate this question using high-performance computing and demonstrate the potential of giga-voxel-resolution computational morphogenesis on a full-scale wing-design problem for an aircraft similar to a Boeing 777 (Fig. 1; see also Extended Data Figs 2 and 3, and Supplementary Figs 1 and 2 for high-resolution images). The extension to being able to solve problems with more than one billion voxels requires several non-trivial challenges to be overcome, including the efficient solution of huge systems of linear equations, tailoring of optimization algorithms, and data transfer and visualization (see Methods). Obtaining the optimized designs presented here required access to massive computational resources with run times of 1–5 days on 8,000 CPUs.

The case study that we present considers the design of the load-carrying internal structure for a full aircraft wing based on the publicly available NASA Common Research Model[10,11]. This wing model is similar to the wing of a Boeing 777 and has a half wing span (length of a single wing) of 27 m and an inner and outer chord (the 'widths' of the wing at the root and the tip) of 12 m and 1.5 m, respectively. The fixed-shape wing is discretized into 1.1 billion voxels (corresponding to a mesh of $3,216 \times 3,456 \times 256$ elements) with a maximum element size of 0.8 cm at the root, which is reasonable for a wing structure of this size[12]. From the NASA model we included two aerodynamic load scenarios, corresponding to angles of attack of 0° and 4° at Mach 0.85 and an altitude of 10,700 m. The outer layer of voxels is fixed to be solid, representing the outer layer of the aerofoil; material can then be freely distributed in the internal part of the wing with no further restrictions (Fig. 2a, top). The optimized design considering a simplified full-wing structure including flaps is shown in Fig. 1, with the top half of the outer layer removed to reveal the optimized interior structures (the full wing is shown in Extended Data Fig. 2). Remarkably, all of the internal structural details appeared spontaneously as a result of the morphogenetic

[1]Department of Mechanical Engineering, Technical University of Denmark, Nils Koppels Allé, Building 404, 2800 Kongens Lyngby, Denmark. [2]Centre for Acoustic-Mechanical Micro Systems, Technical University of Denmark, 2800 Kongens Lyngby, Denmark.

Standard papers (no online supplementary materials)

1 Have you ever tried to reproduce some research results ?

2 Have you ever failed ?

what we can do with standard papers:

read the formulas

believe the results

$ check results

$ reproduce the results

$ see the pictures in detail

$ see the graphs in detail

FAQ:
How numerical integral is implemented in this paper?
How are estimated the optimization hyperparameters ?
...
What are the postprocessing (stress field) tricks?
...

For PhDs…

Don't really understand an algorithm unless you can code it.

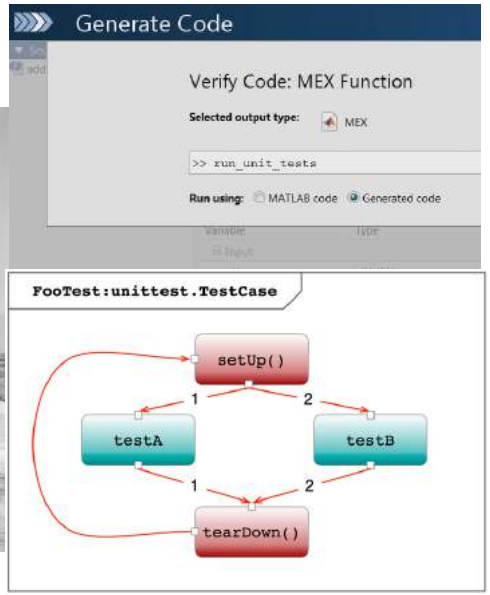
Remember: Software is not your product. → Your product is knowledge:

★ New algorithms (often… improvement of existing algorithms)
★ New theorems (not often…)
★ New models
★ New design, optimum, trade-off etc…

Reproducible research:

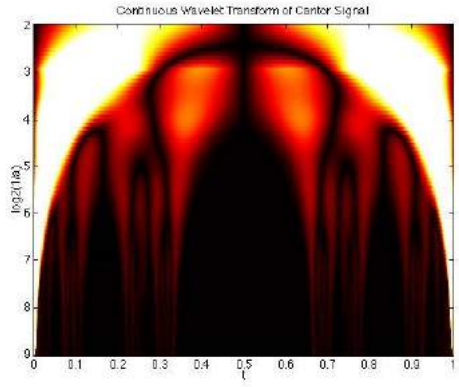
Authors provide all the necessary data and the computer codes to run the analysis again, re-creating the results.

https://hackernoon.com/barba-group-reproducibility-syllabus-e3757ee635cf



Lockheed P-80A airplane (1946). Credit: NASA Commons. — A reminder to test your code.

WAVELAB



Jump to Donoho et al. (2009). This could be the first group to explicitly associate reproducible research with open code and data:

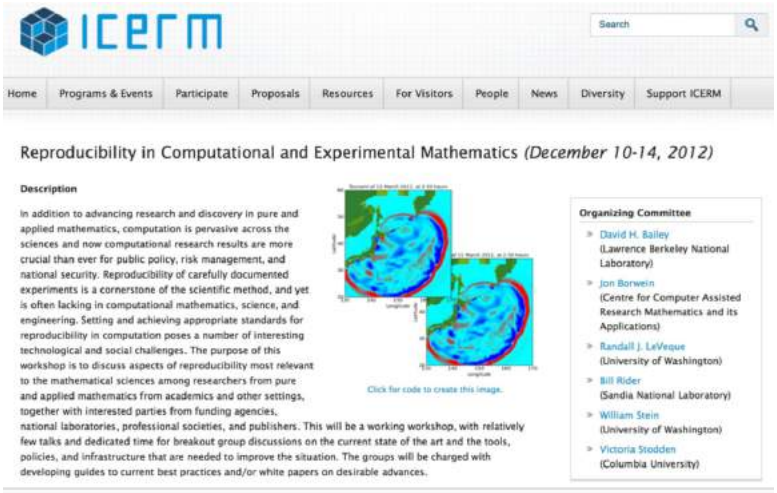
Reproducible computational research, in which all details of computations — code and data — are made conveniently available to others, is a necessary response to [the credibility] crisis.

My favorite quote from Donoho et al. (2009) is: ***"… if everyone on a research team knows that everything they do is going to someday be published for reproducibility, they'll behave differently from day one."***

… si tous les chercheurs d'une équipe savaient qu'ils devaienit publier avec des contraintes de reproductibilité, ils se comporteraient différemment dès le premier jour

BUT In fact

David Donoho, 1998 paraphrased a Stanford Prof



"Really Reproducible Research" pioneered by Jon Claerbout:

"The idea is: An article about computational science in a scientific publication is ***not*** the scholarship itself, it is merely ***advertising*** of the scholarship. The actual scholarship is the complete … set of instructions [and data] which generated the figures."

L'idée est: Un article sur la simulation dans une publication scientifique n'est pas le projet (l'étudiant venant avec sa bourse) en lui-même, c'est simplement la publicité autour de ce projet. Ce projet, lui est l'ensemble … des instructions [et des données] qui ont généré les figures/tableaux

An interesting example…

Running the same code twice with identical input will produce the same output.

If the computation is done in serial, this assumption is good; but with parallel computing, it is not always the case.

Diethelm (2012) ran an experiment using an application of finite-element analysis in computational mechanics. Executing the same simulation (same code, same input data) with varying number of processors gave different results!

The answer

A vector dot-product, computed in parallel over several partial sums. On each execution, individual processors may complete their portion of the sum in different order. In finite precision, addition is not associative and the final sum depends on the order of the partial sum

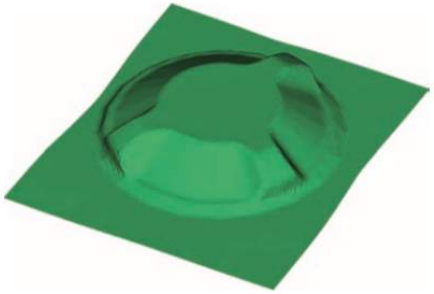


Figure 2. The part to be manufactured. Manufactured from a 0.6-mm thick sheet of steel, the part is about 350-mm long and 400-mm wide. The finite elements used for the simulation have an edge length of 4 mm.

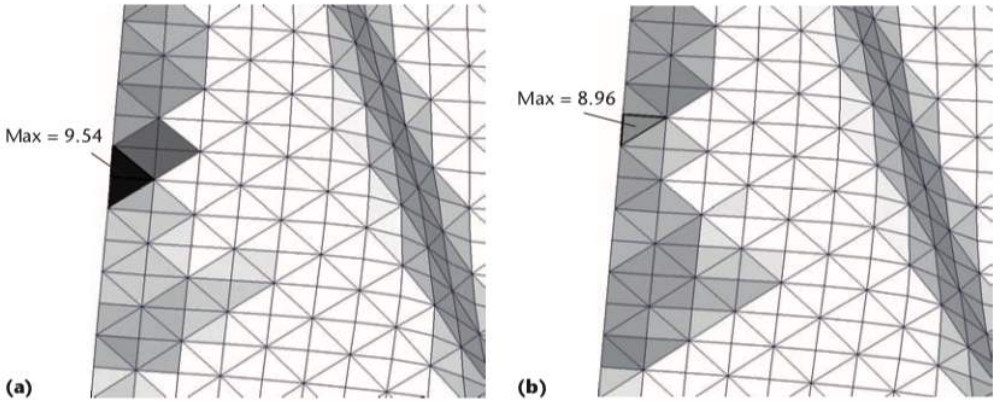


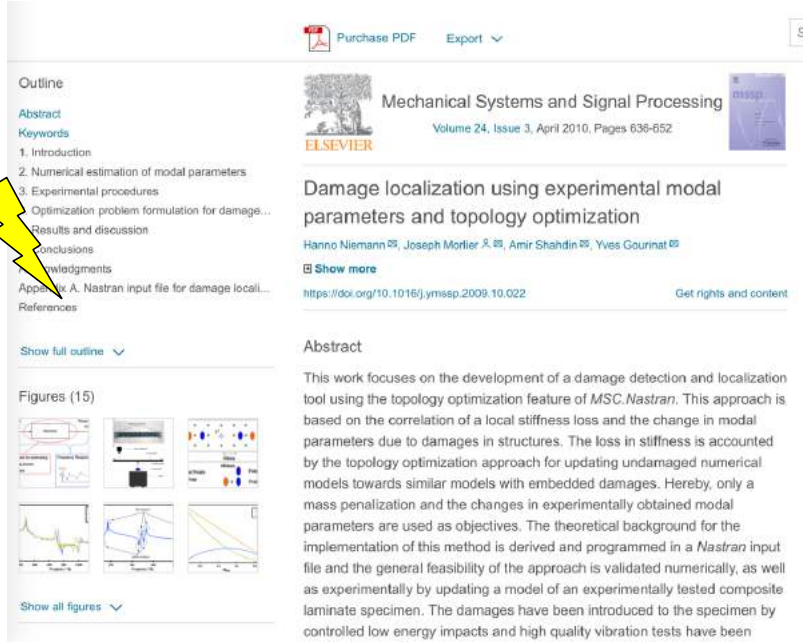
Figure 4. Location of the computed maxima of the sheet thickness change. (a) The simulation with one processor. (b) The second run of the simulation with four processors. The darker the element is colored, the larger the corresponding sheet-thickness change. Elements colored in white have a sheet thickness change of less than 8.5 percent.

My definition

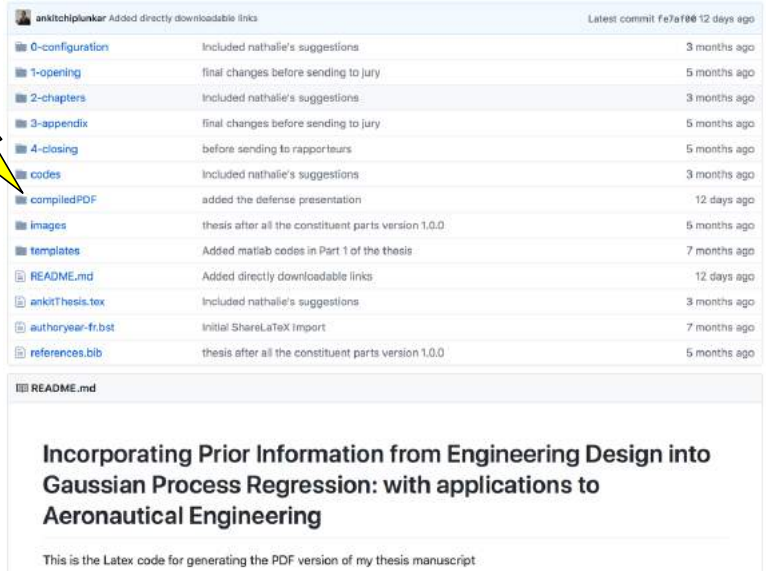
sustainability of the research works
pérennisation des travaux de recherche

"reproducible research" means submitting at minimum:

1. the paper
2. all code & data to reproduce results under open source licenses
3. README files describing code & data



https://github.com/ankitchiplunkar/thesis_isae



PROs and CONs

- From: Survey of the Machine Learning Community, NIPS (Stodden 2010)

Code		Data
91%	Encourage scientific advancement	81%
90%	Encourage sharing in others	79%
86%	Be a good community member	79%
82%	Set a standard for the field	76%
85%	Improve the calibre of research	74%
81%	Get others to work on the problem	79%
85%	Increase in publicity	73%
78%	Opportunity for feedback	71%
71%	Finding collaborators	71%

Survey of the Machine Learning Community, NIPS (Stodden 2010)

Code		Data
77%	Time to document and clean up	54%
52%	Dealing with questions from users	34%
44%	Not receiving attribution	42%
40%	Possibility of patents	-
34%	Legal Barriers (ie. copyright)	41%
-	Time to verify release with admin	38%
30%	Potential loss of future publications	35%
30%	Competitors may get an advantage	33%
20%	Web/disk space limitations	29%

Survey of the Machine Learning Community, NIPS (Stodden 2010)

Response from Within the Sciences

The ***Reproducible Research Standard*** (***RRS***) (Stodden, 2009)
A suite of license recommendations for computational science:
Release media components (text, figures) under CC BY,

https://web.stanford.edu/~vcs/talks/VictoriaStoddenCommuniaJune2009-2.pdf

Benefit for Scientists

- Openness means increased citation.
- Working reproducibly engenders better science.
- Easier for the scientists to build on his or her own work.
- Showcase of skillset for potential collaborators/funders/employers

The pledge: 

http://lorenabarba.com/gallery/reproducibility-pi-manifesto/

I will teach my graduate students about reproducibility.

All our research code (and writing) is under version control.

We will always carry out verification and validation (V&V reports are posted to figshare)

For main results in a paper, we will share data, plotting script & figure under CC-BY

We will upload the preprint to arXiv at the time of submission of a paper.

We will release code at the time of submission of a paper.

We will add a "Reproducibility" declaration at the end of each paper.

I will keep an up-to-date web presence.

→ Higher confidence in our (students) work can create a competitive advantage

→ Our research will become deeper more visible & reusable (even for us)

Some Advices:

Originality: scientific claims contribute something new. % Read Read Read

Publish: search Aims and Scope of your selected journals % with IF >1?

English: simple sentences, check grammar and spelling before give the manuscript to your PhD directors. % journal style: American /British

Unit test: code Validation % trust your results, find bugs

Preprints: upload OATAO+HAL% arXiv?

Supplementary materials: for increasing H factor % If you are lucky, you will start getting emails from (PhD students of) famous professors.

Conferences: for increasing H factor % for networking, and real time snapshots of your research fied (see AIAA, Engopt, Opti, WCSMO…) i.e. NEW IDEAS

!!!!CIFRE THESIS WARNING IP/COPYRIGHT/PATENT

Outputs

Editable source code for reports/papers/notes/codes/livescripts/notebooks/presentations are MANDATORY

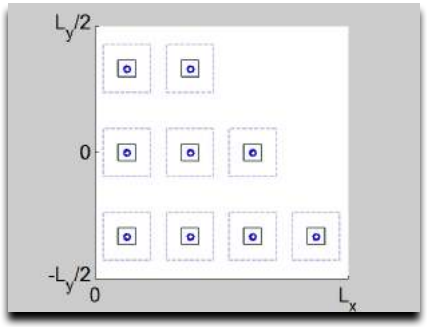
Some help on latex

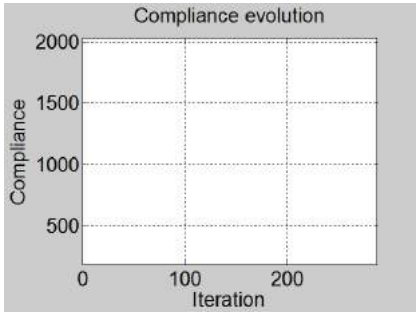
- https://www.codecogs.com/eqnedit.phphttp://detexify.kirelabs.org/classify.html
- http://detexify.kirelabs.org/classify.html
- Sharelatex/overleaf examples !!!

- Some nice video?

Gifs on PPT

avi (compressed on beamer)

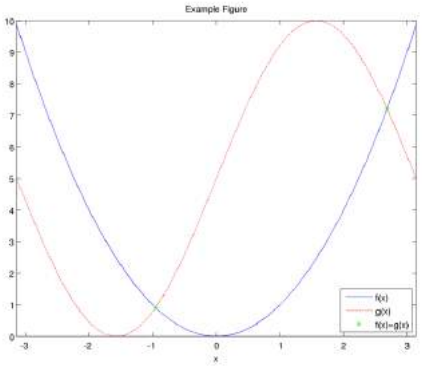


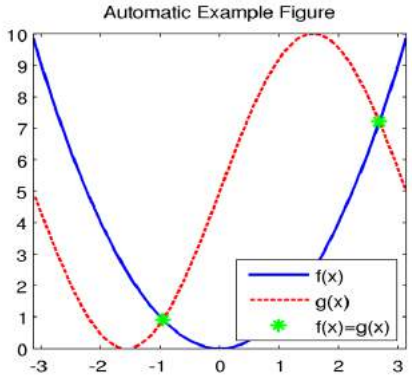


Finally…

Reach HQ standards

- Manuscript
- Presentation





https://dgleich.github.io/hq-matlab-figs/

What is the best way to present your results?

V&V

[1] B. P. Hallissy and C. E. Cesnik,
High-fidelity aeroelastic analysis of very flexible aircraft,
In *Proceedings of the 52th AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference*, pp. 2011–1914 (2011).

[2] M. Patil and D. Hodges,
On the importance of aerodynamic and structural geometrical nonlinearities in aeroelastic behavior of high-aspect-ratio wings,
Journal of Fluids and Structures, 19 (7), pp. 905–915 (August 2004).

Validate your code using bibliography's inputs

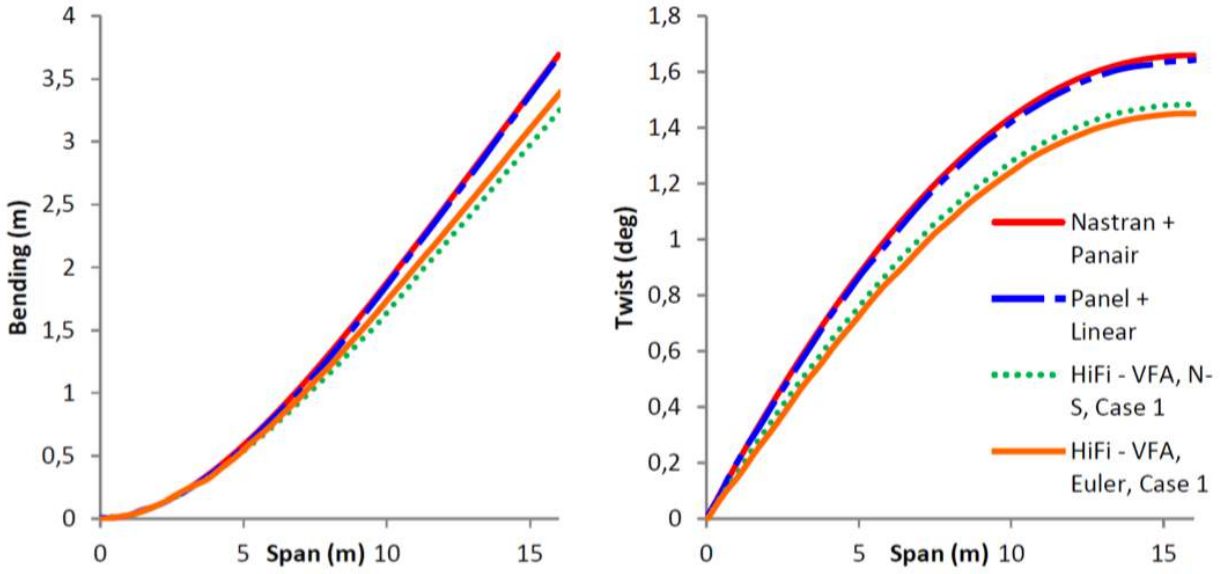
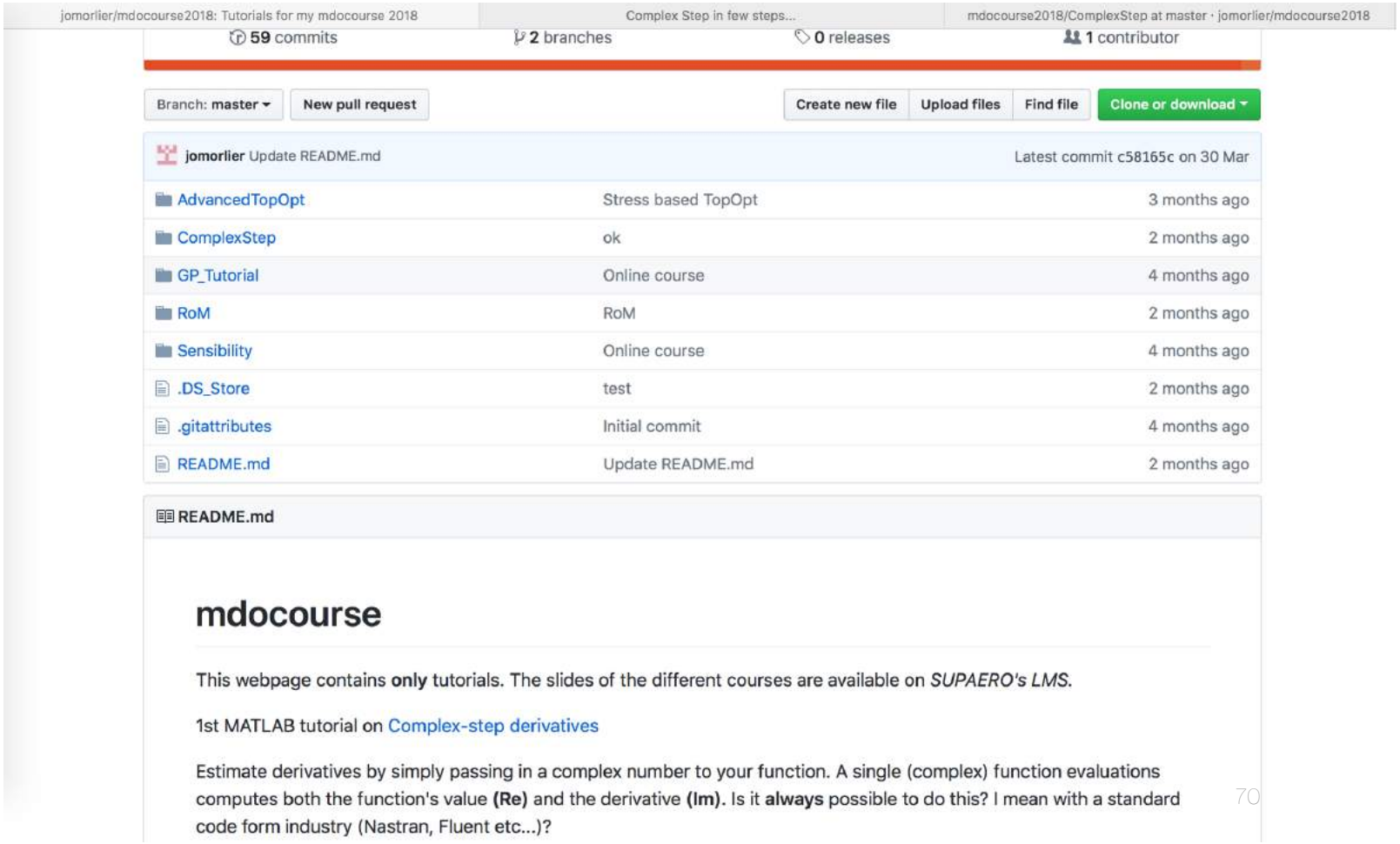


Figure 4.3 –: Spanwise deflection (left) and twist (right). Comparison between the presented approach (Nastran+Panair), and results from references [1, 2]

github

https://github.com/jomorlier/mdocourse2018



Your code

- Is it clean and commented ?
- Is it vectorized, optimized *? Need to provide the dependencies.
- For academic purpose always use interpreted language such as Python/Matlab (Matlab is my favourite due to its documentation/clean references) or julia$
- Use OOP if possible**

$ https://julialang.org

*

https://www.mathworks.com/matlabcentral/fileexchange/5685-writing-fast-matlab-code

https://www.mathworks.com/matlabcentral/fileexchange/22943-guidelines-for-writing-clean-and-fast-code-in-matlab

**

https://en.wikipedia.org/wiki/Object-oriented_programming

github (2)

- Make a tutorial

Complex Step in few steps... | mdocourse2018/ComplexStep at master · jomorlier/mdocourse2018

Complex Step in few steps...

Prof Joseph Morlier, ISAE-SUPAERO

The idea is simple and dates from 1967 [1]. Recent work in multidisciplinary optimization [1] has revived the interest of this method (sensitivity calculation). It is in fact a development of Taylor in the case where F (the function to be derived) is analytic with real values.

Let $F(z)$ be a function and x_0 a real, Taylor development of $F(z)$ gives:

$$F(x_0 + ih) = F(x_0) + ihF'(x_0) - h^2F''(x_0)/2! - ih^3F^{(3)}/3! + ...$$

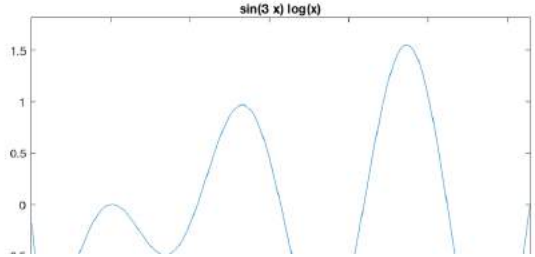
...by taking imaginary part (dividing by h), it comes:

$$F'(x_0) = Im(F(x_0 + ih))/h + O(h^2)$$

Evaluate F with a complex argument $x_0 + ih$, dividing by h, gives the derivative $F'(x_0)$ with an order of precision $O(h^2)$. Let's take $h = 10^{-8}$, the approximation error of $F'(x_0)$ is the same than rounded error.

```
clear all; close all;
%display
f = @(x) sin(3*x)*log(x);
ezplot(f)
```

```
Warning: Function failed to evaluate on array inputs; vectorizing the function may speed up its evaluation and avoid
the need to loop over array elements.
```

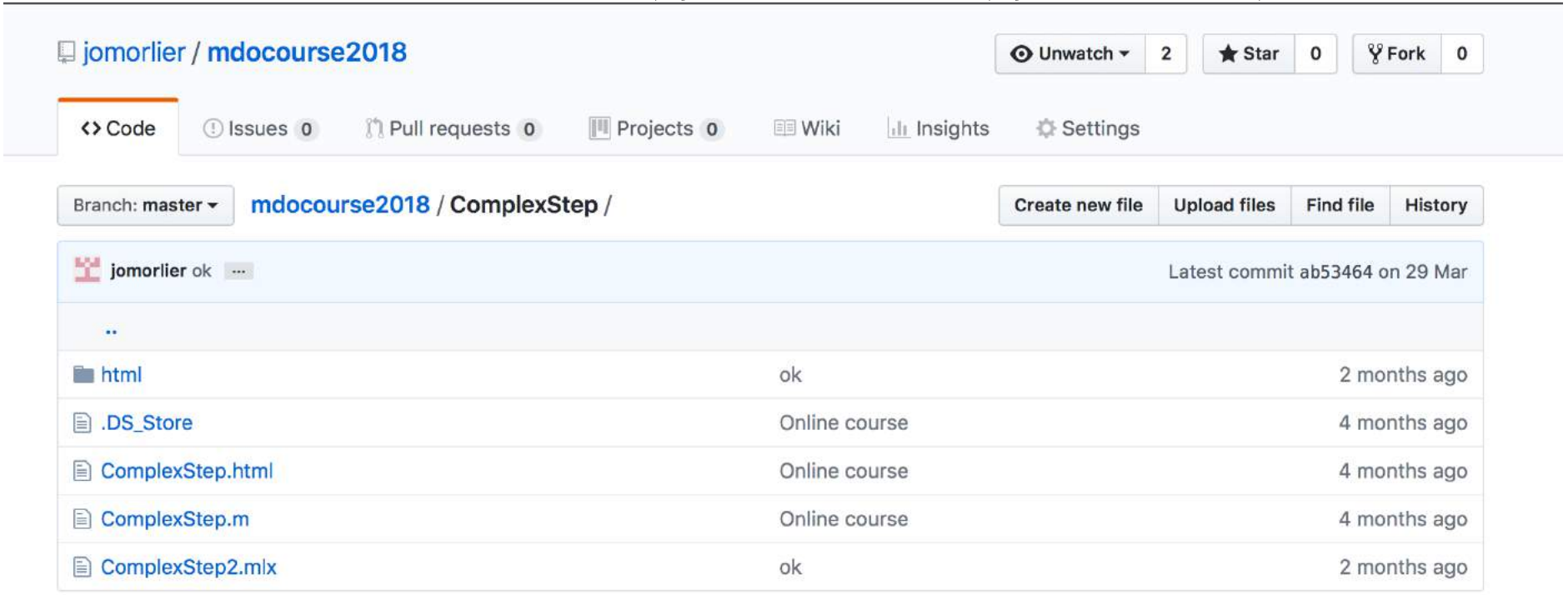


Authors' Note:. the figure is cutted ....

github (3)

In a repertory, upload all the files needed (mlx, m files + html (+ dependencies*), OR

Jupyter Notebook, py files + html)



*Authors' Note: other toolboxes....

It may be interesting to make a short introduction in video (VULGARIZATION)

https://www.youtube.com/watch?v=WiRFuHXHBhk

How can I conclude?

- Recap the big picture
- Recap the improvement
- Quantify the new results
- Future works REALLY needed
- Prepare Backup slides for question
- --> What should the jury/audience ask ???
- Aknowledgment is possible

Read Read . . .Read but WHY ???

Authors' Note:. THIS IS BACKUP SLIDES, YOU'LL NEED TO READ IT !!!

WHY?

This is one of the basic skills of the engineer:

→synthesis of the existing (internal-external)

→potential of new ideas

→risk-taking analysis ...

Above all, Why redevelop the existing?

Objectives of bibliography

→Understand the subject and inspire your work from related work
→Situate your work in a scientific context
→Justify your assumptions and your approach
→Provide a record for future readers of your work

What is expected?

→Select the most relevant articles

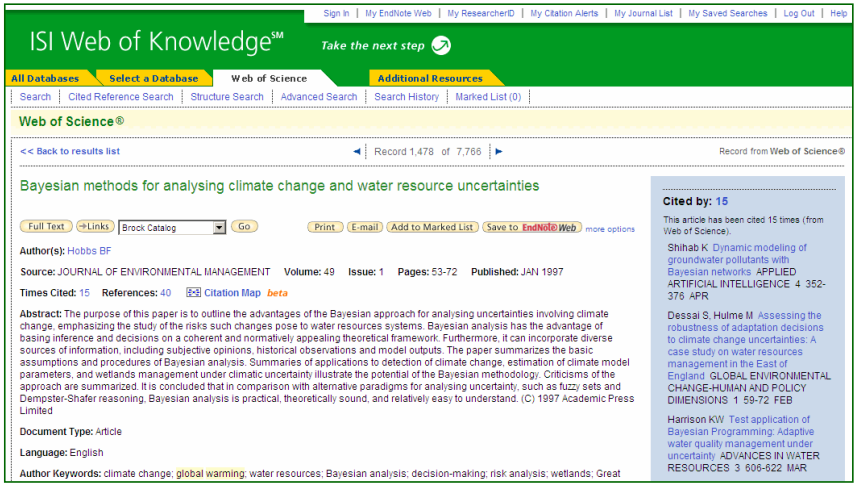
→Create a bibliographic database (to be supported throughout the project)

→Analyse the results in the framework of the project

→Synthesis

TOOLS…

→Web of knowledge : web of science



Elsevier sciencedirect, springer, wiley, sage, sem, asme, aiaa, ieee

BUT MAINLY…

→Google Scholar (http://scholar.google.fr/)

→TYPE SOME KEYWORDS

Networking

→Mendeley BUT MAINLY Research Gate
(https://www.researchgate.net/)