ECCOMAS
European Community on Computational Methods in Applied Sciences

Jyväskylä, Finland, 15th – 17th May 2023

Dedicated to the 80th Anniversary of Jacques Periaux

CM3

Computational Multi-Physics, Multi-Scales and Multi Big Data

TRANSPORT 2023

New Greener and Digital Modern Transport – its Challenges in Design Methods, Tools and Technologies

BOOK OF ABSTRACTS AND PROGRAMME

ECCOMAS Thematic Conference

Federation of Finnish Learned Societies

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

jamk University of Applied Sciences

ECCOMAS Industry Interest Group

Lauri Kettunen, Pekka Neittaanmäki, Tero Tuovinen,
and Dietrich Knoerzer (Editors)

CM3 – TRANSPORT 2023

New Greener and Digital Modern Transport – its Challenges in Design Methods, Tools and Technologies

Book of Abstracts and Programme

An ECCOMAS Thematic Conference

CM3 – Computational Multi Physics, Multi Scales and Multi Big Data

Reports on Scientific Computing and Optimization 1/2023

Editor: Raino Mäkinen
Technical editor: Marja-Leena Rantalainen
Cover: Hanna Salomäki

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ISBN 978-951-39-9610-9 (online)
ISSN 2670-191X

Jyväskylä 2023

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Foreword

The CM3 – Transport Conference 2023 is organized by the University of Jyväskylä, supported by Jamk – University of Applied Sciences, in Jyväskylä/ Finland. The event represents an ECCOMAS Thematic Conference in the context of the activities proposed by the Industrial Interest Group (IIG) of ECCOMAS.

Green and efficient European transport represents an important factor of economic growth to be considered in view of environmental and societal challenges. It is essential to develop the scientific and technological mechanisms to encourage cooperation and competitiveness between transport systems in Europe and in the World. It is also crucial to answer the questions how to conduct and apply research in transport in order to meet these challenges and provide mobility for people and goods at high level of energy efficiency, reliability and safety.

The CM3 Conferences and Workshops are special events for researchers, engineers, industry representatives and policymakers to meet and to discuss green technologies that can drive better transport systems for Europe and beyond. The latest achievements of research and technological developments in Europe and even World-wide are presented and discussed.

The scope of the CM3 – Transport Conference 2023 covers five modes of transport: Aviation and Airports, Automotive, Logistics, Maritime and Harbors and Rail. They are applied to both passenger and freight. The CM3 – Transport Conference 2023 includes plenary sessions addressed by invited speakers and senior technologists, by four Mini Symposia (MS) and two Special Technological Sessions (STS). This event is especially dedicated to the 80th anniversary of Jacques Periaux, who had amongst others been a Distinguished Professor at the University of Jyväskylä for several years.

The Co-chairmen would lie to thank the organising teams of both universities JyU and Jamk for their excellent work in organising this CM3 event, in particular the thanks go to Marja-Leena Rantalainen and Verneri Kilpeläinen of JyU and Kati Valpe-Ojala of Jamk for their effort.

The CM3 organizers wish all participants interesting conference days, many fruitful discussions during this event and a pleasant stay in Jyväskylä.

Jyväskylä, 15 May 2023

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Introduction to Jacques Periaux' Scientific Legacy

Olivier Pironneau

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Jacques Periaux

Our lifelong colleague Jacques Periaux has turned 80 recently and a scientific day is dedicated to him on the occasion of the CM3 – Transport Conference 2023 in Jyväskylä, in mid-May 2023. It is an opportunity to recall some landmarks of his scientific career and his dedication to the scientific community.

Career

Jacques Periaux is born in France during WWII. He went to Université de Paris to study mathematics and mechanics for his Master, completed in 1965. His first research position was at ONERA [1] for his military duties for 18 months. In parallel he decided to join the new Master program created by Prof. Jacques-Louis Lions in applied mathematics, which he completed in 1969. In 1970 he joined the recently founded numerical simulation group at the aerospace company Dassault Aviation headed by Dr. Pierre Perrier. Unlike many engineers, Jacques never left research. He obtained a PhD in applied mathematics in 1979 and a HdR (Hability to direct PhDs) in 1989.

From 2007 to 2010 Jacques had a TEKES position as a Finnish Distinguished Professor at the University of Jyväskylä. In 2010 he received a UNESCO chair position at CIMNE, the computational institute of the University of Catalonia UPC, in Barcelona, Spain.

During the last three decades, Jacques Periaux has initiated many scientific and technical cooperations in Europe (with the EU), Australia, China, Japan, and the USA. He has written some 300 scientific papers and published 20 proceedings and one co-authored book.

Contribution to Science

Jacques attended a conference in Canada in 1971, where the first application of the finite element method (FEM) to fluid flow was discussed [2]. P. Perrier immediately saw the potential of the method for airplane design. Hence Jacques became perhaps the second scientist to use FEM for airplane design in 2D and 3D [3].

Quickly Jacques and his team headed towards nonlinear equations for transonic and compressible flows. A cooperation with the numerical team of J.-L. Lions and Roland

Glowinski at INRIA was initiated, and in 1978 the first complete aircraft was simulated by the transonic equation. It was a World premiere, for which the contribution of Jacques was essential.

To handle the nonlinearities a least square method in the Sobolev space, H−1 was used because one could use distributed optimal control [4], and that space is adapted to second order equations like the transonic equation, the Navier-Stokes equations and the Maxwell equations for stealth airplanes. Many articles from that period are still up-to-date because the algorithms have not changed: GMRES, DDM (Domain Decomposition Methods), FDM (Fictitious Domain Methods), HUM (Hilbert Uniqueness Methods).

From 2000 onward Jacques concentrated on DDM and Evolutionary Algorithm for optimal design like Genetic Methods. These are summarized in his book Evolutionary Optimization and Game Strategies for advanced Multi-Disciplinary Design published on 2015 in the Springer series Intelligent Systems, Control and Automation.

Consequently, Jacques became a World expert in the following topics:

1. Numerical Solution of Non Linear Partial Differential Equations
2. Finite Element Methods for CFD and CEM
3. Aerodynamic Design of manned/unmanned aircraft vehicles
4. Domain Decomposition on parallel architectures
5. Fictitious Domain Methods
6. Mesh adaptation with a posteriori error estimates
7. Multidisciplinary Design Optimization
8. Optimal Control Theory, Evolutionary Algorithms and Game Theory

Contribution to the Organization of Science

Jacques has a gift for public relations, which has allowed him to transport ideas and people from countries and continents. He has been instrumental in the creation or participation of France in a large number of projects, like:

- HERMES (1986-92)
- ECARP (1994)
- INGENET (1998)
- FLOWNET (1999)
- GAMNI (1983)
- ERCOFTAC (1985)

- ECCOMAS (1992)
- MACSINET (2001)
- The DDM conference series (1998-2010)

As said earlier he has strong links with the UPC, the University of Jyväskylä, the University of Houston-Texas and the University of Nanjing in China. [5]

Honors

Jacques' tremendous scientific energy and valor has been granted with the following recognitions:

- IMA Fellow, 1986
- Doctor Honoris Causa, NUAA, Nanjing, P.R. of China, 1989
- AIAA Associate Fellow, 1992
- French Science et Defense Award, 1993
- Chevalier de l'Ordre des Palmes Académiques, 1996
- Doctor Honoris Causa, BUAA, Beijing, P.R. of China, 1998
- Friendship Certificate and Medal Award, Jiangsu Province, 2002
- National "Friendship Award", SAFEA Beijing, 2010
- Member of the International Academy of Astronautics (IAA): 2011

We all wish Jacques Periaux a very happy birthday and many returns.

References

[1] ONERA – The French Aerospace Lab, https://www.onera.fr/en
[2] Norries D.H., G. de Vries: The Finite Element Method, Academic Press, New-York (1973).
[3] J. Periaux, Int. J. Numer. Methods in Eng. 775-831 (1975).
[4] J.-L. Lions: Optimal Control of Distributed System, Springer 1988
[5] Open China EU aeronautical R&T cooperation

Personal Message to the 80th Anniversary of Jacques Periaux

Pierre Perrier

Former Head of the Theoretical Aerodynamic Department of Dassault-Aviation,
Member of the French Academy of Technology, Paris,
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Dear Professors of the University of Jyväskylä, Professors from many other universities as well as good friends of Professor Jacques Périaux,

You are celebrating today the 80th birthday of our friend, aside from a scientific meeting on computations of climate prediction for years to come. First of all, let me apologize for not being here today. A toe broken last February on a dark and steep flight of stairs during the preparation for a scientific seminar in March in the south of France, which I haven't completely recovered from, unables me to be in your beautiful and efficient university with you all.

It has become difficult over the years to bring together the six members of a famous team of academic and industrial workers. Their success story has gained some celebrity in the first great achievements in the field of Computational Fluid Dynamics… with the nickname of « the G-P4- B ». It united 6 researchers involved in the advancements, 4 having a first letter P in their name and two others having a G and a B. Among these 4 Ps, two are in this room today, Pironneau and Périaux.

But let me start with the beginning!

In 1970 in France, the Direction for Research in the Military Field DRME (Directions des Recherches et Moyens d'Essais) of the Ministry of Defense wanted to set up a triangular program for support of better computational design in the Aeronautical industry, and first in fighters, with the cooperation of academic and industrial design office.

And on a Saturday morning in 1970 took place the first meeting of a young candidate with a doctorate level in my office at Dassault Aviation for the selection of a mathematician (first employment!) as a link to a team of professors and researchers to be involved in the common program: A first challenge for Jacques Périaux.

As an applied mathematician in Numerical Fluid Mechanics, he was invited to enhance the viability of the best ideas in method and algorithm with the Institute of Informatics INRIA and Paris Sorbonne University (the fluid being a continuous medium thus of infinite dimension and thus posing a problem of convergence for the nonlinear PDE models after discretization!) Jacques Périaux being in DRME (with Ingénieur de l'Armement Vuillard), just graduated his DEA in Numerical Analysis with J. L. Lions and de Possels during his military service at Balard (the location of

the DRME south of Paris) and was providentially finding himself available just at this date. There was a lot of randomness in this situation, but some may also call it destiny, for this is how Jacques Périaux, a university student in the Department of Theoretical Fluid Dynamics, found himself in my office the unique place for what would be the Golden Age of CFD. Together with Olivier and Roland, you did very « useful » mathematics applied to aerodynamics in the collective context of a team that succeeded first in 1976 with the introduction of the finite element method in Fluid Mechanics applied in 3-D to a complete civil and military aircraft and later much more complex flows around re-entry vehicles returning from space!

That was quite a beginning, and you have kept on doing applied mathematics in the aeronautical field at first, and later with increasing involvement in teaching and researching in foreign universities spreading the "French way" of doing such mathematics to the benefit of many students.

Meilleurs vœux (best wishes),

Pierre Perrier

Plenary Session 1

Chair: Pekka Neittaanmäki

Speakers:

Trond Kvamsdal, SINTEF and NTNU:
Enabling Technologies for Predictive Digital Twins

Nicolas Gauger, Technical University of Kaiserslautern-Landau (RPTU):
Efficient Industrial Aerodynamic Shape Optimization by Combining Sobolev Methods with Arbitrary Parameterizations

Enabling Technologies for Predictive Digital Twins

Trond Kvamsdal[1,2], Eivind Fonn[2], Adil Rasheed[2,3], Vasileios Tsiolakis[1], and Harald van Brummelen[4]

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Keywords: Digital twin, reduced order modelling, hybrid analysis and modelling

We adopt the following definition of a Digital Twin [1]: A digital twin is defined as a virtual representation of a physical asset, or a process enabled through data and simulators for real-time prediction, optimization, monitoring, control, and decision-making.

To enable predictive twins, we utilize Hybrid Analysis and Modelling (HAM) [2-4] that combines classical Physic-Based Methods (PBM) accelerated by means of Reduced Order Modelling (ROM) [5, 6] together with Data-Driven Methods (DDM) based on sensor measurement analysed by use of Machine Learning (ML). In Fig. 1 we show how we envision a predictive digital twin may be utilised for optimal operation of commercial and naval ships.

We will in this talk present different ROM and HAM techniques applicable for fluid flow and structural mechanics relevant for the maritime sector and renewable energy. We will also discuss opportunities and challenges related to use of predictive digital twins in general and for the transport sector in particular.

Acknowledgement The authors acknowledge the financial support from the Research Council of Norway and the industrial partners of the two projects CONWIND: *Research on smart operation control technologies for offshore wind farms* (project no. 304229), and the *FME NorthWind*: *Norwegian Research Centre on Wind Energy* (project no. 321954).

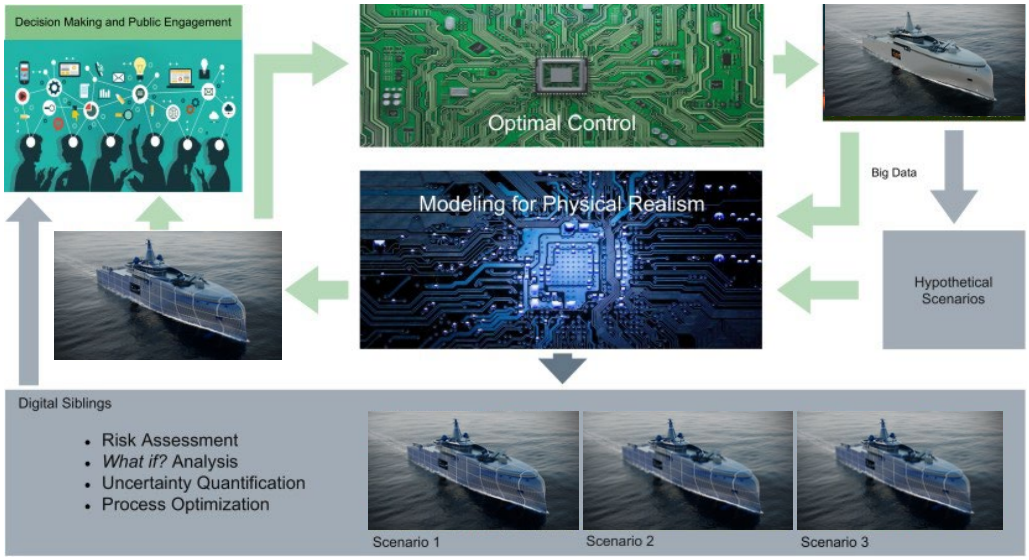

Fig. 1 The overall view on predictive digital twins for a ship. Green arrows symbolize real time data acquisition for HAM based modelling and decision support. Grey arrows symbolize hindcast and simulations of future scenarios.

References

[1] A. Rasheed, O. San, T. Kvamsdal. Digital Twin: Values, Challenges and Enablers from a Modeling Perspective. IEEE Access, 8:21980--22012, 2020, 2020.

[2] O. San, A. Rasheed, T. Kvamsdal. Hybrid analysis and modeling, eclecticism, and multifidelity computing toward digital twin revolution. GAMM-Mitteilungen, e202100007. 2021.

[3] S. Pawar, O. San, B. Aksoylu, A. Rasheed, T. Kvamsdal. Physics guided machine learning using simplified theories. Physics of Fluids, 33, 011701, 2021.

[4] S. S. Blakseth, A. Rasheed, T. Kvamsdal, O. San. Deep neural network enabled corrective source term approach to hybrid analysis and modelling. Neural Networks 146, 181-199, 2022.

[5] E. Fonn, H. van Brummelen, T. Kvamsdal, and A. Rasheed. Fast divergence-conforming reduced basis methods for steady Navier-Stokes flow. Computer Methods in Applied Mechanics and Engineering, 346:486-512, 2019.

[6] V. Tsiolakis, T. Kvamsdal, A. Rasheed, E. Fonn and H. van Brummelen, Reduced order models for finite-volume simulations of turbulent flow around wind-turbine blades. Journal of Physics: Conference Series, Volume 2018, 012042, 2021.

Efficient Industrial Aerodynamic Shape Optimization by Combining Sobolev Methods with Arbitrary Parameterizations

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Keywords: Sobolev methods, general parameterizations, shape optimization

On the one hand, Sobolev gradient smoothing can considerably improve the performance of aerodynamic shape optimization and prevent issues with regularity. On the other hand, Sobolev smoothing can also be interpreted as an approximation for the shape Hessian. This paper demonstrates, how Sobolev smoothing, interpreted as a shape Hessian approximation, offers considerable benefits, although the parameterization is smooth in itself already. Such an approach is especially beneficial in the context of simultaneous analysis and design, where we deal with inexact flow and adjoint solutions, also called One Shot optimization. Furthermore, the incorporation of the parameterization allows for direct application to engineering test cases, where shapes are always described by a CAD model. The new methodology presented in this paper is used for reference test cases from aerodynamic shape optimization and performance improvements in comparison to a classical Quasi-Newton scheme are shown.

Anniversary Session 1 for Jacques Periaux – Different Applications of Optimization Tools

Chair: Trond Kvamsdal

Speakers:

William E. Fitzgibbon, Department of Mathematics, University of Houston:
Advective Diffusive Models for the Spread of Infectious Disease

Jean-Antoine Desideri, Acumes Project Team, Centre INRIA d'Université Côte d'Azur:
Combining Pareto Optimality with Nash Games in Multi-Objective Prioritized Optimization of an Aircraft Flight Performance

Domenico Quagliarella, Italian Aerospace Research Centre (CIRA):
A Natural Evolution-Based Approach to Aerodynamic Shape Design. From Early Experiments with Airfoils to Multi-Objective and Robust Optimization

Advective Diffusive Models for the Spread of Infectious Disease

William E. Fitzgibbon

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Keywords: Advection diffusion equations, dissipative reaction systems

Our concern is mathematical systems that model the reactive transport of species (biological or chemical) across broad highly heterogeneous domains. Our models couple advection diffusion equations with locally defined fully or partially dissipative reaction systems. Although such systems have application to a variety ecological or to biological processes our focus shall be the pathogen driven spatio-temporal spread of infectious disease across a geographic area.

Combining Pareto Optimality with Nash Games in Multi-Objective Prioritized Optimization of an Aircraft Flight Performance

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Keywords: Pareto optimality, Nash games, concurrent engineering

The presentation is meant to introduce a case study of prioritized multi-objective optimization of the flight performance of an Airbus-A320-type aircraft conducted in cooperation between the INRIA Project Team Acumes and the Information Processing and Systems Department (DTIS) of ONERA Toulouse [2]. The prioritized optimization algorithm has been defined mathematically and proved convergent in [1]. It is here illustrated by the treatment of a numerical testcase meant to be part of a preliminary aircraft design phase. Two primary cost functions (take-off fuel mass, f_1; operational empty weight, f_2) and one secondary (ascent-to-cruise-altitude duration,f_3) have been minimized under functional constraints: interval bound on static margin and upper bound on wingspan. Six design variables were used to calibrate wing geometry, mean aerodynamic chord and take-off thrust potential. The designs were evaluated by means of the FAST-OAD opensource software developed by ONERA and ISAE-SUPAERO, and the prioritized optimization was conducted by the INRIA Nash-MGDA software. From a point of Pareto-optimality of the sole pair (f_1, f_2), considered preponderant, the climb duration f_3 is reduced drastically by a one-shot procedure establishing a continuum of Nash equilibria.

The application of this procedure is far less computationally demanding than is the numerical establishment of the Pareto-front associated with the three cost functions together, while the Pareto-optimality of the whole set of cost functions is only marginally degraded in agreement with the asymptotic analysis.

References

[1] J.-A. Désidéri, Adaptation by Nash games in gradient-based multi-objective/multidisciplinary optimization, in JANO13, Mathematical Control and Numerical Applications, Khouribga, Morocco, vol. 372, Springer Proceedings in Mathematics and Statistics, 2021. https://hal.inria.fr/hal-03430972.

[2] J.-A. Désidéri, J. Wintz, N. Bartoli, C. David, and S. Defoort, Combining Pareto Optimality with Nash Games in Multi-Objective Prioritized Optimization of an Aircraft Flight Performance, Research Report RR-9490, Inria - Sophia Antipolis ; Acumes, Oct. 2022. https://hal.inria.fr/hal-03817789.

A Natural Evolution-Based Approach to Aerodynamic Shape Design: From Early Experiments with Airfoils to Multi-Objective and Robust Optimization

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Keywords: Aerodynamic shape optimization, evolutionary methods, multi-objective optimization, airfoil design

Natural evolution has produced countless beautiful shapes that adapt in creative and very different ways to the environment in which they are immersed [1]. They have always inspired humankind in an attempt to imitate their beauty and effectiveness. The immense variety and richness of Nature have always fascinated and intimidated humankind, and not long after Darwin began to pierce the veil of mystery that surrounded it, discovering the laws of natural evolution [2], we began to hope to be able, partially and imperfectly, to reproduce its mechanisms. The seminal and visionary works of Holland [3], Goldberg [4], and Schwefel [5] led to the implementation of computer systems capable of emulating, albeit imperfectly, the mechanisms of natural evolution and, finally, the commitment and support and vision of some researchers such as Jacques Périaux [6], have led to the development of a robust community of researchers and engineers using evolutionary algorithms in advanced research projects or optimization engineering practice.

This talk focuses on the applications of evolutionary approaches to aerodynamic shape optimization. It illustrates the pros and cons of this approach in a journey that ranges from the first applications to airfoil design to robust and multi-objective optimization.

References

[1] Sean B. Carroll, “Endless Forms Most Beautiful”, W. W. Norton, 2005.
[2] Charles Darwin, “On the Origin of Species”, Johnn Murray, London, 1859.
[3] John H. Holland, “Adaptation in Natural and Artificial Systems”, The University of Michigan Press: Ann Arbor, Michigan, 1975.
[4] David E. Goldberg, “Genetic Algorithms in Search, Optimization and Machine Learning”, Addison-Wesley: Reading, Massachusetts, 1989.
[5] Hans-Paul Schwefel, “Evolution and Optimum Seeking”, John Wiley & Sons: New York, USA, 1994.
[6] Gabriel Winter, Jacques Périaux, Manuel Galán, Pedro Cuesta, “Genetic Algorithms in Engineering and Computer Science”, John Wiley & Sons Ltd., England, 1995.
[7] Domenico Quagliarella, Antonio Della Cioppa, “Genetic algorithms applied to the aerodynamic design of transonic airfoils”, Journal of Aircraft , Vol. 32, No. 4, 1995.

[8] D. Quagliarella and E. Iuliano, “Robust Design of a Supersonic Natural Laminar Flow Wing-Body”, IEEE Computational Intelligence Magazine, 12(4), 14-27, (2017).
[9] E. Morales and D. Quagliarella, “Risk Measures in the Context of Robust and Reliability Based Optimization,” in Vasile M. (eds) Optimization Under Uncertainty with Applications to Aerospace Engineering. Springer, Cham, (2021).

Anniversary Session 2 for Jacques Periaux – Advanced Methods in Optimizations

Chair: William Fitzgibbon

Speakers:

Carlo Poloni, University of Trieste / ESTECO S.p.A.:
1993–2023 – 30 Years of Evolution in Design Optimization

Boris Naujoks, TH Köln – Univ. of Appl. Sciences:
Preliminary title: 25 Years in Design Optimisation - an Evolution of Methods?

David Greiner, University of Las Palmas, ULPGC:
Enhancing Computational Engineering through Game Theory Based Evolutionary Algorithms and Machine Learning

Alain Dervieux, INRIA:
Variational Study of Mesh and Shape Optimization

Dietrich Knoerzer, Aeronautics Consultant:
34 Years of European Research Cooperation on Computational Methods in Aeronautics

1993–2023 – 30 Years of Evolution in Design Optimization

Carlo Poloni

University of Trieste and ESTECO S.p.A.

Design optimization has emerged as a vital area of research in engineering, aiming to improve the performance and efficiency of systems, structures, and products. Over the last three decades significant contributions to this field have been made pushing the boundaries of design optimization methodologies and tools. This abstract provides an overview of the key advancements in design optimization research spearheaded by Carlo Poloni during the past 30 years showing the “fill-rouge” connected with the research activity of Jacques Periaux.

The research has focused on the development of robust and efficient optimization algorithms that can handle complex design problems with multiple objectives and constraints including both deterministic and stochastic optimization techniques, providing engineers with a diverse range of tools to tackle real-world design challenges.

The presentation starts from the first paper about shape optimization in fluid dynamics published in 1993 that triggered the start of a long-lasting collaboration with Jacques Periaux. It will continue touching the papers published in the occasion of EuroGen Conferences and will end with real-life examples of aerospace achievements in currently flying airplanes.

25 Years in Design Optimisation - an Evolution of Methods?

Boris Naujoks

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The talk summarises the development of (evolutionary) optimisation techniques over the last 25 years with a special focus on design optimisation. Thus, it briefly covers, single- as well as multi-objective optimisation techniques and put some attention to the integration of surrogate-assisted methods. The talk concludes with a collection of open issues in the field and provides possible research direction to address these.

Enhancing Computational Engineering through Game Theory Based Evolutionary Algorithms and Machine Learning

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Keywords: Computational engineering, evolutionary algorithms, game strategies, multidisciplinary design optimization (MDO), machine learning

In the broad field of computational engineering, design optimization is gaining interest and application in real world problems (e.g.: digital twins) due to the continuous advance of computational power availability and the improvement in simulation and optimization methods [1]. Among them, evolutionary algorithms (EAs) are powerful and flexible tools whose requirement of a high number of fitness evaluations could be improved using parallel EAs, game theory based EAs [2, 3], and metamodels / surrogate models (based on machine learning techniques, as deep learning, or others).

Application of those methodologies, single or combined, in the field of computational mechanics are shown in this work, where an enhanced performance is achieved with some of the abovementioned techniques. Also, some applications in the field of biomedical engineering, particularly cochlear implants simulation, were shown.

Acknowledgements This research was supported by ACIISI - Gobierno de Canarias and European FEDER Funds Grant EIS 2021 04. Also, Project support funding from the Ministerio de Ciencia, Innovación y Universidades, Gobierno de España, grant contract: PID2019-110185RB-C22, and from the Agencia Canaria de Investigación, Innovación y Sociedad de la Información, Consejería de Economía, Conocimiento y Empleo del Gobierno de Canarias, Grant Contract Number: PROID2020010022, and European Regional Development Funds (ERDF/FEDER) is gratefully acknowledged.

References

[1] D. Knoerzer, J. Periaux, T. Tuovinen, *Advances in Computational Methods and Technologies in Aeronautics and Industry*, Computational Methods in Applied Sciences, Vol. 57, Springer, 2022.

[2] J. Periaux, F. González, C.L Dong Seop, *Evolutionary Optimization and game Strategies for Advanced Multi-Disciplinary Design, Application to Aeronautics and UAV Design*, Springer, 2015.

[3] D. Greiner, J. Periaux, J.M. Emperador, B. Galván, G. Winter, Game theory based Evolutionary Algorithms: a review with Nash applications in structural engineering optimization problems, *Archives of Computational Methods in Engineering*, 24 (4), 703-750, 2017.

Variational Study of Mesh and Shape Optimization

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Keywords: Computational fluid dynamics, mesh adaptation, shape design, adjoint state

Some years ago, the interactions between the team of Jacques Periaux in Dassault-Aviation and the team of Roland Glowinski were focusing on variational methods, as for example functional least squares [1]. A central notion in variational methods for design and meshes is the "adjoint state". Indeed, considering a CFD modelization represented by the partial differential equation $\Psi_{\mathrm{CFD}}(\mathrm{W}) = 0$ and once a cost function or scalar output is chosen, $j = J(\mathrm{W})$ s.t. $\Psi_{\mathrm{CFD}}(\mathrm{W}) = 0$ the corresponding adjoint state, written in short,

$$\mathrm{W}^* = \left[\frac{\partial \Psi_{\mathrm{CFD}}}{\partial \mathrm{W}}\right]^{-1} \frac{\partial \mathrm{J}}{\partial \mathrm{W}}$$

can be used for both shape and mesh sensitivity computation. The shape is parametrized by a parameter γ and the mesh is parametrized by a Riemannian metric $\mathcal{M}$.

In a first part we recall how shape sensibilities $\partial j / \partial \gamma$ can be computed. We then (second part) recall and discuss how mesh sensitivities $\partial j / \partial \mathcal{M}$ can be computed either based on sensors, or based on the functional j, or based on an error norm [2] In a third part, starting from the analogies between the computations of both sensitivities, we discuss the possible answers to be proposed to the question of combining mesh adaptation and design optimization. Examples of mesh adaptation, design optimization and combination of both are then proposed.

References

[1] M.-O. Bristeau, R. Glowinski, J. Periaux, P. Perrier, and O. Pironneau. On the numerical solution of nonlinear problems in fluid dynamics by least squares and finite element methods (II). application to transonic flow simulations. Comput. Meths. Appl. Mech. Engrg., 17/18:619–657, 1985.

[2] A. Dervieux, F. Alauzet, A. Loseille, and B. Koobus. Mesh adaptation for Computational Fluid Dynamics, t.1. ISTE Ltd and John Wiley & Sons, New York (ISBN: 9-781-78630-832-0), 1st edition, 2023.

34 Years of European Research Cooperation on Computational Methods in Aeronautics

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When in the second European Research Framework Programme in 1989 the first call for proposals was launched for specific aeronautics research, computational methods on code validation, mesh generation and design optimisation were addressed among the first series of successful proposals. Jacques Periaux' professional and scientific carrier was closely linked to the collaborative research activities on European level. From his academic education, he was a mathematician and worked for the French Aerospace manufacturer Dassault Aviation on computational methods. In 1989, he became the coordinator of the first successful European project on optimum design. At that time, the limited computer power allowed only simple methods (Panel or Euler methods) and coarse grids.

The increasing computer performance in the nineties allowed to pick up the idea of John Holland from 1975 to use robust genetic algorithms for the optimisation process. Together with the University of Las Palmas de Gran Canaria, Jacques Periaux organised in 1995 the first short course. Later the European network INGENET established the bi-annual thematic conference EUROGEN that received increasing interest. Today the use of hybrid techniques of a combination of robust genetic algorithms with fast gradient methods is a standard design tool in industry.

Based on a strong European scientific cooperation especially with INRIA (France), Jyväskylä (Finland) and CIMNE (Spain), Jacques Periaux was able to expand his scientific network to a global dimension. World-wide contacts were established. He had already many years of experience with China, when he launched the first EU-China network AeroChina in 2005. Intensive cooperation between Europe and China took place in the following 15 years by several joint networks. The results were a number of joint co-funded research projects. In two of them: MARS and DRAGY, he was personally involved.

Anniversary Session 3 for Jacques Periaux – Messages from all over the World

Chair: Carlo Poloni

Speakers:

Hiroshi Suito, Tohoku University, Japan:
Causal Inference for Power Grid Dynamics

Eugenio Oñate, CIMNE/UPC, Spain:
A personal message to Jacques Periaux

Randolph Bank, UC San Diego, USA:
PPLTMG – A Parallel Adaptive Method

Shukun Zhang, Chinese Aeronautical Establishment (CAE), China:
An Interpretation of China's Actions for Global Climate-Neutral Aviation

Zhili Tang, Nanjing Univ. of Aeronautics & Astronautics, China:
Joint Exploration in the Endless Frontiers of MDO

Srinivas Karkenahalli, University of Sydney, Australia:
Optimisation in Aerospace and Biomedical Engineering

Causal Inference for Power Grid Dynamics

Hiroshi Suito

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Keywords: Causal inference, causality graphs, explainability

This presentation introduces a research effort to extract causal relations from time series data of electrical consumption obtained from a power grid serving a university campus. In fact, electrical consumption exhibits different characteristics and dynamics depending on building types and diverse external conditions such as seasons, temperatures, and school calendars. Causal relations between such factors and electrical consumption from power grid systems are expected to provide control strategies for effective reduction of campus electricity costs.

Causality graphs, which should be Directed Acyclic Graphs (DAGs), constructed from data are rather complicated. Certain strategies must be developed to impart sufficient explainability to them. The mathematical basis for causality inference must be strengthened using combinatorics and mathematical logic, as along with high-performance machine learning techniques and cognitive sciences to enhance the explainability. Moreover, the network controllability should be evaluated and analyzed using appropriate network centralities.

This research is a part of Discovery Intelligence Laboratory co-established by Fujitsu Ltd. and Tohoku University, which is intended to extend application areas to address widely diverse social issues and to construct robust mathematical bases for them.

Jacques Periaux – a Great Scientist, the Best Colleague and a Friend for over 40 Years *(a personal message)*

Eugenio Oñate

Professor at Universitat Politécnica de Catalunya, Barcelona, Spain
Founder of CIMNE, onate@cimne.upc.edu, www.cimne.com
Former President of ECCOMAS, IACM and SEMNI

I write these lines on the occasion of the 80th birthday anniversary of Prof. Jacques Periaux, and I start by expressing my best wishes to him for this great occasion.

I have known Jacques for over 40 years. During this time, I have been able to appreciate his many personal talents. Among these I highlight his passion for research, his motivation to push the development of computational science and technology, mainly in the field of aeronautical engineering, beyond traditional academic and geographical frontiers, and his strive for promoting cooperation between applied mathematicians and engineers from all over the world.

He was one of the key architects in building the computational engineering community in Europe and beyond. He was one of the founders and first president of the European Community in Applied Sciences and Engineering (ECCOMAS). His work was essential for establishing cooperation between ECCOMAS and the main scientific organizations in the field of computational engineering at worldwide level, such as the International Association for Computational Mechanics (IACM), and also at national level, such as the Spanish Association for Computational Mechanics and Engineering (SEMNI).

E. Oñate, J. Periaux and D. Knoerzer at CIMNE, Barcelona, 28th April 2017

I emphasize the role of Jacques in promoting research in the field of aeronautics at the International Center for Numerical Methods in Engineering (CIMNE) in Barcelona, Spain. After his initiative, several research projects were developed at CIMNE since 1987, many of them with financial support from the European Commission under the supervision of Dr. Dietrich Knörzer, and with participation of the main stakeholders at academia and industry in aeronautics. He has been very active in promoting scientific cooperation with universities and research centers in China in the aeronautics field.

Jacques is still very active as a UNESCO Professor on Numerical Methods in Engineering at CIMNE. I deeply thank him for his contributions, support and friendship during many years and wish him all the best at personal and professional level in the years to come.

PPLTMG – A Parallel Adaptive Method

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Keywords: PPLTMG, parallel adaptive method, adaptive algorithms

We describe an approach to parallel adaptive methods. This approach features low communication costs, and relatively modest modifications of traditional sequential adaptive algorithms. An example using the author's software package PLTMG is given. This topic was chosen for this talk because the original suggestion for making a parallel version of PLTMG came from Jacques Periaux (PPLTMG) [1].

References

[1] R. E. Bank, M. Holst, B. Mantel, J. Periaux, and Ch. H. Zhou; CFD PPLTMG Using A Posteriori Error Estimates and Domain Decomposition, ECCOMAS '98, John Wiley & Sons, (1998)

An Interpretation of China's Actions for Global Climate-Neutral Aviation

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Keywords: Climate-neutral aviation, MDAO, MBSE, big data

One major application area of the CM3 – Transport 2023 conference is climate-neutral aviation. Recent actions of China government and aviation industry targeting carbon dioxide peaking before 2030 and carbon neutrality before 2060, are interpreted with a bird's eye view focusing on aviation industry, hopefully for fitting better the science & technology research requirements at large, and particularly in the field of Computational Multi-physics, Multi-scales and Multi big data.

It is concluded that the Multidisciplinary Design Analysis Optimization (MDAO) technology is crucial towards climate-neutral aviation, integrating MDAO into the aircraft lifetime through Model Based Systems Engineering (MBSE) has been well implemented and practiced, in which various applications of high-fidelity aeronautics numerical simulation technology are inherently multi-physics and multiscales, and Big Data technology in the field of civil aviation has been a global concern.

References

[1] SCIO white paper. Responding to Climate Change: China's Policies and Actions. October 2021, accessed February 24, 2023.
[2] MEE report. China's Policies and Actions for Addressing Climate Change (2022). October 2022, accessed February 24, 2023.
[3] SCIO white paper. China's Green Development in the New Era. January, 2023, accessed February 24, 2023.
[4] CAAC. 2022 China Civil Aviation Green Development Policy and Action. December 30, 2022, accessed February 24, 2023. 33(12):1-11. (In Chinese)
[5] Marina Kousoulidou, Daniele Violato. Towards Climate-Neutral Aviation: Contributions from Horizon 2020 Projects Implemented by INEA. ISBN 978-92-9208-100-3 - DOI: 10.2840/047167, European Union, 2020, accessed September 19, 2022.
[6] Lauren Hadnum, Mark Pacey, Katy Milne. FlyZero Technology Roadmaps - Technology Pathways to Enable Zero-Carbon Emission Flight. FZO-IST-MAP-0012, March 2022, accessed Sepember 26, 2022

[7] AGILE 4.0 Project Consortium. AGILE 4.0 - Towards cyber-physical collaborative aircraft development. Available online: https://www.agile4.eu/, accessed.February 24, 2023.
[8] Boggero, L., Lefèbvre, T., Vankan, W.J., Beijer, B., Saluzzi, V., & Nagel, B. (2022, September 5). The AGILE4.0 MBSE-MDAO Development Framework: overview and assessment. 33rd Congress of the International Council of the Aeronautical Sciences (ICAS), Stockholm. https://doi.org/10.5281/zenodo.7070940
[9] Gerrit Burmester, Hui Ma, Dietrich Steinmetz and Sven Hartmannn, Big Data and Data Analytics in Aviation, in Advances in Aeronautical Informatics - Technologies Towards Flight 4.0, Springer International Publishing AG, part of Springer Nature 2018, ISBN 978-3-319-75057-6, https://doi.org/10.1007/978-3-319-75058-3

Joint Exploration in the Endless Frontiers of MDO

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Keywords: MDO, Nash equilibrium theory, decision-making mechanisms, aircraft optimization design

This presentation briefly reviews the joint efforts I have made with Professor Jacques Periaux in the field of MDO over the past thirty years. In particular, some achievements have been made in applying game theory to establish theoretical models and efficient optimization algorithms for solving multidisciplinary optimization problems. This mainly includes:

1. Applying of Nash equilibrium theory in economics to engineering science, establishing alternating and symmetric information transfer Nash strategies, and numerical solution methods for multidisciplinary optimization design problems of aircraft with conflicting objectives.
2. Robust control theory is developed and applied to aircraft optimization design, and robust shape optimization design method based on uncertainty analysis is developed. It has been successfully applied to aircraft drag reduction, high lift device design, flow control and other issues.
3. Combined with three decision-making mechanisms of Pareto, Nash and Stackelber, a multi-level nested parallel optimization algorithm is studied. It can solve large-scale multidisciplinary optimization design problems.

Optimisation in Aerospace and Biomedical Engineering

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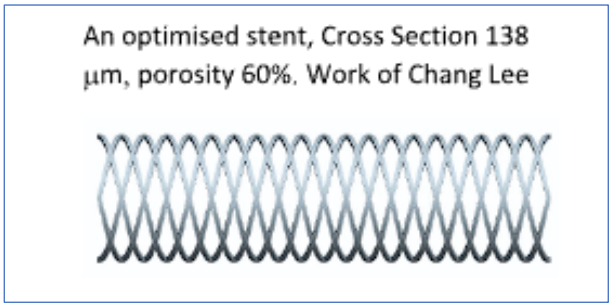
Keywords: Design optimisation, aerodynamic shapes, biomedical engineering, cardiovascular flows

Design optimisation studies were undertaken by our group mainly due to the support and encouragement given to us by Prof. Jacques Periaux in 1999. The main aim was to develop procedures to optimise aerodynamic shapes with multiple as well as multi-disciplinary objectives. Genetic Algorithms, which later got merged into Evolutionary Algorithms were the starting point. The first challenge was to speed up the Genetic Algorithms, which are intrinsically slow. This led to the development of a *Hierarchical Parallel Algorithm and Asynchronous strategy* resulting in a substantial speed-up. Capabilities to handle uncertainty in data and to evolve a *Robust Design* were also introduced. Later this was extended to *Multi-Disciplinary Design Optimisation*, MDO. Various cases of optimisation of including those of UAVs were handled.

With encouragement from Tohoku University, I undertook the work on the optimisation of stents using the *Exploration of Design Space* strategy in collaboration with Profs. S Obayshi and K Ohta in 2006. For cardiac stents, it was discovered that the strut width, height and spacing were the design variables and it was required to minimise the recirculation of flow past the struts.

For the cerebral stents, used to control blood flow into the aneurysm sacs, porosity and pore density formed the design variables. Velocity and vorticity within the aneurysm sac had to be minimised. The research continued for a few years culminating in the design of a three-dimensional stent shown in the picture.

The research then started addressing some of the interesting problems in cardiovascular flows in humans including aneurysms, Aortic Dissection, and Arterio -Venous Malfunction (AVM). At present, we consider the issue of Computing Aortic Stiffness where we calculate abnormal pressures that can occur within the aorta due to a variety of reasons.



Plenary Session 2

Chair: Jacques Periaux

Speakers:

Xavier Bertrand, Airbus:
Hybrid Rapid Aerodynamic Modelling at Airbus

Olivier Pironneau, Academy of Sciences of France:
Radiative Transfer for Atmospheres with Clouds

Hybrid Rapid Aerodynamic Modelling at Airbus

Xavier Bertrand

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Keywords: Aircraft aerodynamics, deep learning, artificial intelligence (AI)

The main difficulty of aircraft design can be summarised in a simple question: how to converge towards the right product at the right time and at the right cost with the most appropriate process for each step of the a/c development?

Among all the disciplines involved in the overall aircraft design, aerodynamic models aim at providing mandatory inputs for Handling Qualities, Performance and Loads thanks to various numerical and experimental means, such as CFD or wind tunnel tests. Developing the right product at the right time and at the right cost, can be transposed to the aerodynamic perimeter to select and use efficiently the most relevant capabilities at each stage of the development process, to evaluate multiple aircraft configurations.

Deep learning and Artificial Neural Networks have been successfully applied to many fields. Image recognition, object detection or natural language processing are some of the most active fields of Data Science research. The ability of computer vision algorithms in particular, based on convolutional neural networks, have been demonstrated to detect and model features of images, from the most basic (vertical or horizontal lines) to the most complex (human faces, eyes...).

Aerodynamics models, either based on global aircraft coefficients or skin pressures, based on large volumes of data produced by experimental or numerical means, include some specific visual patterns like stalls at high angle of attack, supersonic rooftops or stagnation points. These peculiar visual phenomena can be captured and modelled quite properly thanks to deep learning algorithms.

In this context, combining deep learning-based data fusion, data scaling or high dimensional surrogate modelling with more traditional aerodynamic capabilities (rapid CFD such vortex lattice methods, RANS CFD or wind tunnel tests), appears to be a game changer to generate quickly Aerodynamic Models with the right level of fidelity, in particular in the earlier phases of the aircraft design process.

In this presentation, we will give some examples of how these digital techniques are combined with more classical aerodynamic capabilities at Airbus as Hybrid Rapid Aerodynamic Modelling to produce quickly accurate aerodynamic models. A particular focus on the challenges to be tackled in the near future for an industrial company like Airbus will also be given.

Radiative Transfer for Atmospheres with Clouds

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Keywords: Radiative transport, H-matrix, finite element, contrail, cloud

To study the temperature in a gas subjected to electromagnetic radiations, one may use the Radiative Transfer equations coupled with the Navier-Stokes equations. The problem has 7 dimensions, however with minimal simplifications it is equivalent to a small number of integro-differential equations in 3 dimensions. A numerical implementation using an H-matrix compression scheme allows us to measure the effect of clouds and airplane contrails on the temperature in the atmosphere. The result is very fast and the method is capable of handling variable absorption and scattering functions of spatial positions and frequencies.

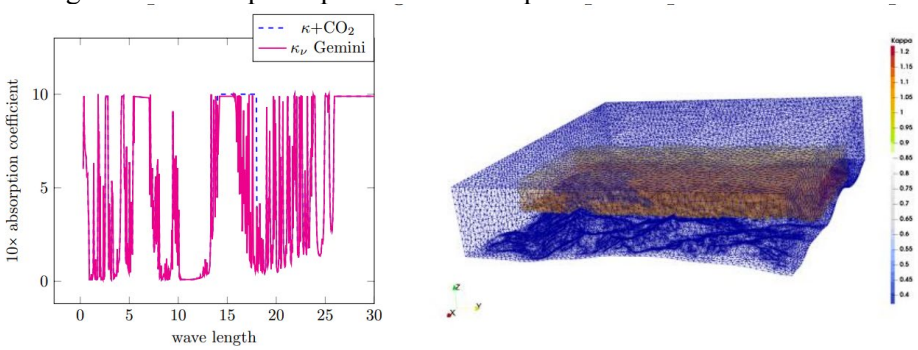

Fig. 1: Left: Absorption κ_ν versus wavelength (c/ν) read from the Gemini data site. A CO_2 perturbation of κ_ν is shown too. Right: The topography and the mesh and the x-dependency of κ. The level surfaces of κ show a fractal cloud between 0 and 1 as a y-elongated region above Chamonix between altitude 3000 m and 7000 m.

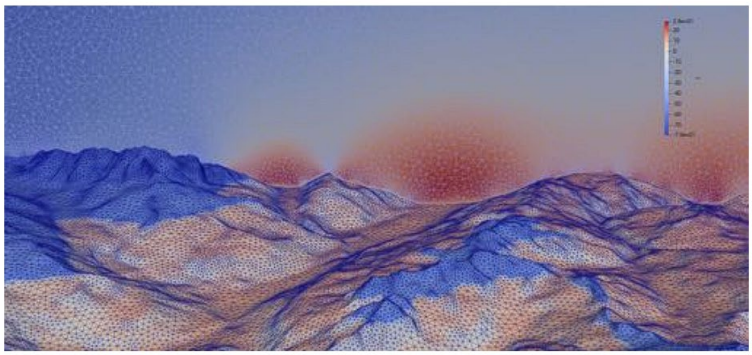

Fig. 2: Ground and vertical temperatures (in °C) in the valley of Chamonix. The mesh is shown in blue on the ground and the intersection of the mesh with the vertical plane is shown in white.

Session on Applications of Computational Methods

Chair: Olivier Pironneau

Speakers:

Yoshiaki Abe, Tohoku University:
Digital Aircraft Design with Carbon Fiber Reinforced Thermoplastics

Alberto Clarich, ESTECO:
Uncertainty Quantification Based on Multifidelity Metamodels and Reduced Order Models

Michael Emmerich, Leiden University:
Multi-objective Green Delivery Routing with Flexible Time Windows: Minimizing Fossil Fuel Consumption vs. Maximizing Quality of Service

Digital Aircraft Design with Carbon Fiber Reinforced Thermoplastics

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Keywords: Aircraft design, CFRTP, CFRP

Digital design of aircraft has been one of the most challenging topics in engineering fields, which requires highly multidisciplinary simulation tools and has yet to be fully realized in industries. This study has developed a numerical framework of designing aircraft wings with carbon fiber reinforced thermoplastics (CFRTPs).

Three composite materials, T700G/2592, T800S/3900-2B, and T700G/LM-PAEK, were chosen to compare CFRTP to CFRP. T700G/LM-PAEK is one of the possible CFRTPs as a material for the future aircraft, whereas T700G/2592 and T800S/3900-2B are composed of thermosetting resin and used for comparison. T800S/3900-2B uses a fiber with higher stiffness and strength than T700G/2592 or T700G/LM-PAEK. The experimental measurements of T700G/LM-PAEK were utilized.

T700G/LM-PAEK shows higher open-hole tension (OHT) strength than the T700G/2510 and can tolerate higher strain levels for tensile loading. Therefore, T700G/LM-PAEK realize approximately 40% thinner thicknesses on lower panel than CFRPs, resulting in a weight reduction of approximately 19%. Nevertheless, such thinner panels resulted in aeroelastic disadvantages and a greater loss of lift owing to torsional deformation. Consequently, compared to the T700G/2510, T700G/LM-PAEK needs to be set with approximately 9.2% higher angle of attack to obtain a design lift coefficient of 0.5.

Uncertainty Quantification Based on Multifidelity Metamodels and Reduced Order Models

Alberto Clarich[1], Luca Battaglia[1] and Livia Trambaiolo[2]

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Keywords: Uncertainty quantification, optimization, machine learning, multi-fidelity, ROM

Optimization under uncertainties is achieving more and more agreement in the industrial design community. In fact, most of the industrial processes are permeated by uncertainties, including for instance dimensional tolerances and fluctuations in the operating conditions. The uncertainties are commonly transferred to the performance of the system, which cannot be determined by a single value, but rather by a statistical distribution of results. To deal with industrial problems characterized by a large number of uncertainties and expensive simulation time, it is particularly important to develop methodologies which are at the same time accurate, and that can rely on a reduced number of sample evaluations.

In this paper, we propose two different methodologies for this scope, applied to aeronautical test cases. The first one takes advantage of multifidelity meta-models, which conjugates few high-fidelity simulations (HF) with low-fidelity ones (LF), to evaluate the propagation of the uncertainties using Cokriging algorithm. The method is particularly efficient for large number of uncertainties since the number of samples is linearly correlated with the number of uncertainties while other methods, for instance the ones based on Polynomial Chaos Expansion, may require at least a quadratic correlation. The second methodology is instead based on the UQ application of Reduced Order Models (ROM), that define an equivalent CFD model in function of a given set of parameters, by interpolating a sampling series of CFD snapshots. Surrogate models like Deep Learning can be used for the interpolation, or as alternative POD (Proper Orthogonal Decomposition) methods which are instead based on the interpolation of a reduced number of modes (the principal components). In both cases, the ROM model can be used to instantly evaluate a Monte Carlo DOE at the variation of the uncertain parameters, allowing the evaluation of the uncertainty propagation of the vectorial field of interest.

References

[1] B. Peherstorfer, K. Willcox and M. Gunzburger. Survey of multifidelity methods in uncertainty propagation, inference, and optimization, SIAM Review. Vol. 60, No. 3, pp. 550-591, 2018.

[2] A.I.J. Forrester, A. Sóbester and A.J. Keane. Multi-fidelity optimization via surrogate modelling. In Proceedings of the royal society, Mathematical, physical and engineering sciences, 2007.

[3] R.F. Genesio and M. Milanese. A note on the derivation and use of reduced-order models. IEEE Transactions on Automatic Control. 21.1, 118-122, 1976.

Multi-objective Green Delivery Routing with Flexible Time Windows: Minimizing Fossile Fuel Consumption versus Maximizing Quality of Service

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Keywords: Green logistics, delivery routing, multi-objective optimization, flexible time windows, hybrid transport

The Delivery Routing Problem with Time Windows (DRTW) is a logistics optimization problem that involves determining the most efficient route for a fleet of vehicles to deliver goods or services to customers within specific time windows. The challenge is to satisfy customer demands while minimizing delivery costs and maximizing vehicle utilization. DRTW considers various constraints, such as vehicle capacity, travel time, and time windows, and aims to find a solution that satisfies all these constraints while minimizing the total travel time and distance.

Our proposal is to develop a multiobjective solver for delivery routing problems with hybrid trucks. These trucks use diesel engines for long haul distances and electric engines for short range drives within urban areas. We assume that customers have some flexibility with regards to time windows and can provide a ranked list of preferred time windows. The selection of the time window introduces a decision variable for each delivery that influences the objective of user satisfaction and fuel consumption, which are potentially conflicting. For example, using a less preferred time window might help to avoid a detour and thereby reduce fuel consumption.

Our solver aims to meet the client's preferences for delivery time windows and provide a cost-efficient delivery route that minimizes fossil fuel consumption. We use tri-objective optimization algorithms to solve this problem and analyze the shape of the Pareto frontier. The route planner can select a good compromise solution by identifying knee point solutions on the 3-D Pareto optimal surface. Our solver is based on previous studies for vehicle routing [2] and green label models for flexible time windows [1]. For fuel cost estimates and hybrid engine modeling, we use insights summarized in existing literature. Lastly, we use the open-source DESDEO solver, developed by the University of Jyväskylä, Finland, which allows for a rich variety of visual analytics packages for result visualization and subsequent interactive decision making [4].

Acknowledgements Burak Gulmez acknowledges financial support under the TUBITAK 2219 postdoctoral fellow grant scheme (Scientific and Technological Research Council of Turkey).

References

[1] I. Charpentier and M. Ghemires. Agatz, N., Fan, Y., & Stam, D. (2021). The impact of green labels on time slot choice and operational sustainability. Production and Operations Management, 30(7), 2285-2303.

[2] Yang, Z., van Osta, J.P., van Veen, B., van Krevelen, R., van Klaveren, R., Stam, A., Kok, J., Bäck, T. and Emmerich, M., 2017. Dynamic vehicle routing with time windows in theory and practice. Natural computing, 16, pp.119-134.

[3] Elangovan, R., Kanwhen, O., Dong, Z., Mohamed, A., & Rojas-Cessa, R. (2021). Comparative Analysis of Energy Use and Greenhouse Gas Emission of Diesel and Electric Trucks for Food Distribution in Gowanus District of New York City. Frontiers in big Data, 4, 693820.

[4] Misitano, G., Saini, B. S., Afsar, B., Shavazipour, B., & Miettinen, K. (2021). DESDEO: The modular and open source framework for interactive multiobjective optimization. IEEE Access, 9, 148277-148295.

MS-1 – EU-funded Research in Transport: Aviation Transport

Chair: Dietrich Knoerzer

Speakers:

Leonidas Siozos-Rousoulis, EC, CINEA:
Contributions of EU-Funded Projects Managed by CINEA Towards Greener and Digital Transport

Daniel Lindblad, Imperial College London:
An Overview of Jet-Airframe Interaction Noise Research in the DJINN Project

Grazia Piccirillo, POLITO:
ESATTO – A Holistic Multi-Disciplinary Framework for Future Supersonic Aviation

David Dumas, CENAERO:
Design Strategies Using Hybrid Models for Manufacturing and Vulnerability of Composite Structures

Rajaa El Akoury, IMFT Toulouse:
Travelling Wave Actuation on a Morphing Wing Prototype of A3xx Type for Aerodynamic Performance Increase by Means of Numerical Simulation

Contributions of EU-Funded Projects Managed by CINEA Towards Greener and Digital Transport

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Keywords: Aviation, waterborne transport, climate impact, emissions, energy efficiency, conceptual design, aerodynamics and aeroacoustics, digital twin, machine learning, composite manufacturing

The "European Green Deal" [1] has set ambitious goals for the transport sector, calling for a 90% reduction in its greenhouse gas emissions by 2050. To achieve this systemic change, the European Commission has adopted the "Sustainable and Smart Mobility Strategy" [2] which aims to ensure that the EU transport sector is fit for a clean, digital and modern economy. Among others, this strategy indicates that all modes of transport should be made more sustainable and outlines the need for the decarbonisation and energy efficiency improvement of aviation and maritime transport in particular. To this end, digitalisation and automation will become important drivers to deliver on these greening objectives and to maintain and reinforce the EU's leadership and competitiveness. It is also essential that key digital enablers for design, manufacturing and automation are in place for all transport modes. This includes electronic components for mobility, network infrastructure, cloud-to-edge resources, data technologies and governance, as well as Artificial Intelligence (AI).

Thanks to the continuously increasing capabilities of High Performance Computing (HPC) hardware, digitalized design can facilitate the testing, certification and deployment of the innovative solutions required to minimize the environmental impact of airborne and waterborne transport. Further advancement of multi-disciplinary design optimization methodologies and simulation tools, along with integration of AI methods and big data analysis are thus important challenges to address, in order to reduce emissions during the industrial production process and the entire product lifecycle.

The European Commission's European Climate, Infrastructure and Environment Executive Agency (CINEA) is currently implementing a broad portfolio of collaborative R&I projects, funded under Horizon 2020 and Horizon Europe, which are contributing to the European Green Deal through the aforementioned specific technological challenges. These projects are developing and applying advanced methods for modelling, simulation, optimization and design of technologies contributing to the mitigation of the environmental impact in airborne and waterborne transport. The portfolio of EU-funded projects managed by CINEA is expected to be further enhanced by selecting new projects from upcoming calls for proposals within the Horizon Europe Cluster 5 on Climate, Energy and Mobility.

References

[1] European Commission, Communication from the Commission, The European Green Deal, COM(2019) 640 final, 2019.
[2] Sustainable and Smart Mobility Strategy – putting European transport on track for the future, COM/2020/789 final; https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0789

An Overview of Jet-Airframe Interaction Noise Research in the DJINN Project

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Keywords: NRT, UHBR, computational aeroacoustics, CAA, discontinuous Galerkin, jet noise, installation noise

The DJINN project is a collaborative effort between 13 leading European universities, research institutions, and industrial partners. The aim of the DJINN project is to reduce the amount of jet installation noise (DJINN = Decrease Jet INstallation Noise) generated by future ultra-high-bypass ratio (UHBR) turbofan engines and business jets. To this end, advanced noise reduction technologies (NRT) such as chevrons, porous trailing edges, and closed-loop active flow control are being developed for two realistic aircraft geometries; a UHBR engine installed under a wing and a business jet engine installed close to a tail-plane. To develop these noise reduction technologies, small-scale experimental tests combined with fast numerical methods were first used. The noise reduction potential of these NRTs was then further quantified by an extensive test campaign in the DLR AWB wind tunnel. In addition to this, industry-level high-fidelity numerical methods based on hybrid RANS-LES turbulence modeling were used to assess the geometries.

Typically, the highest frequencies predicted by these methods correspond to a non-dimensional Strouhal number of St = 3. Although this covers the dominant frequencies for jet installation noise, it is not high enough to cover the whole relevant spectrum, thereby preventing these numerical methods from being used to fully assess new aircraft designs. Therefore, new, advanced numerical methods capable of reaching St = 10 are also developed in the DJINN project. These include the high-order discontinuous Galerkin method, the high-order Spectral Difference method, the low-dissipation, low-dispersion LD2 finite-volume scheme, and the GPU-CABARET method. These methods were initially validated on two generic single-stream jets, for which extensive experimental data is available. Later in the project, some of these methods will be used to predict the noise generated by the proposed NRTs installed on the two aircraft platforms.

The aim of this talk is to give a brief overview of the DJINN project, including the strategies used to reach the aforementioned goals. The talk will also present some of the numerical methods used to assess the NRTs. This talk is targeted towards a wide audience, including industry practitioners and academics alike.

ESATTO - A Holistic Multi-Disciplinary Framework for Future Supersonic Aviation

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Keywords: MORE&LESS project, supersonic aviation, environmental impact, multi-disciplinary optimization

The EU-funded MORE&LESS project addresses the challenge to shape global environmental regulations for future supersonic aviation. The environmental impact of supersonic aircraft will be assessed by a holistic analysis using the ESATTO framework. Recommendations for new guidelines to allow for the introduction of supersonic aircraft will follow consequently.

ESATTO will result from the integration of all the upgraded software tools used within the project in a unique workflow, encompassing different disciplines (aerodynamics, propulsion, aeroacoustics, pollutant emissions, and environmental impact) and their mutual relationships, thus allowing to perform a multi-disciplinary optimization of supersonic aircraft' trajectories and operations. Already accepted and validated software tools will be enhanced and extended to widen their applicability to supersonic aviation, benefitting from low and high-fidelity modelling activities and test campaigns. ESATTO structure will be composed of three main modules: Rapid Aircraft Prototyping tool, Environmental Modelling tool, and Trajectory Calculation Module.

The Rapid Aircraft Prototyping tool, named ASTRID-H 2.0, developed at Politecnico di Torino will be enhanced by integrating surrogate models for aerodynamic and propulsive characterization into the conceptual design process. This will serve to refine the preliminary data obtained during the first iteration loop of conceptual design, for both biofuel and liquid hydrogen supersonic aircraft.

For the Environmental Modelling tool, the task starts from assessing the possibility of using already existing emissions forecast tools for supersonic aviation and developing ad-hoc routines. The IMPACT tool is selected to prepare the input requested to perform the environmental impact analysis both for fuel emissions and noise. In addition, the HISAC 2.0 climate function developed by DLR, which will include updated routines for estimating air quality emissions and climate impact, will be used for atmospheric modelling.

For the simulation of the flight missions within the multi-objective optimization framework, the Multi-Mode Trajectory Analysis (MMTA)-Tool is adapted to various operating scenarios and extended to an interactive module structure. Module A represents the state of the art, Module B is capable to simulate supersonic missions of the Mach 2 vehicles and Module C focuses on the Mach 5 vehicles.

A federated architecture is considered for the set-up and integration of the overall framework. Specifically, all the upgraded tools will be connected exploiting the collaborative environment for Multidisciplinary Design Analysis and Optimization (MDAO) developed in the H2020 AGILE project.

Current activities focus on updating the software tools used in the individual modules. The progress towards extending the models to supersonic case studies will be presented in more detail. At the same time, work is ongoing on the set-up of the overall architecture leveraging the AGILE paradigm. Interface requirements, cross organisational aspects and data models will be specified, also providing a general overview of the multidisciplinary optimization process.

Design Strategies Using Hybrid Models for Manufacturing and Vulnerability of Composite Structures

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Keywords: Composites materials, hybrid models, curing, damage, vulnerability, high performance computing, machine learning, uncertainty quantification

New certified designs for structures are critical for the upcoming changes in conception of aircraft architectures. Breakthroughs in design and new strategies for a better use of material and integration of functions in aircraft are required. Digital conception and simulation will play a role to reach a certified design that includes production scenarios before full manufacturing.

The level of complexity of phenomena being solved through dedicated modelling techniques is constantly evolving and faces many challenges in validation and exploitation. For better use of these methods, scalability, speed and representativity need to be addressed. In the DIDEAROT project, ongoing until 2026, the design process is addressed using appropriate Machine Learning surrogates, benefiting from High Performance Computing.

The presentation will outline the roadmap and first results of the project for robust optimization of composite structures focused on digital predictions of two key aspects in its lifetime:

1. Manufacturing: predicting distortions, stress build-up and assembly challenges for ever-more integrated industrial scale composite parts
2. Dynamic loads and impact: predicting damage and effects from loads occurring at high speed or repeated loads over time that can lead to critical certification conditions.

Micro- and meso-models are computed and build upon relying on digital technologies (data or simulation driven) to obtain efficient high-quality models to ensure optimized design approaches up to an industrial scale.

For mechanical behaviour of composites including damage, this means that accurate representation of the evolution of the material properties are achieved at the ply and structural level using hybrid models trained through a database of microscale RVE models run on a multitude of load cases [1], [2], [3].

Manufacturing simulations using phenomenological curing models use a building block. Hybrid models for the component level, capable of handling many design parameter evaluations will feed the full-scale simulations to reach robust design for manufacturing requirements [5], [6]. In parallel, improvements in the numerical schemes and high-performance computing of these multi-physical problems will finally validate the distortion and stress build-up in the structure [4].

References

[1] L. Wu, V. D. Nguyen, N. G. Kilingar, and L. Noels. A recurrent neural network-accelerated multiscale model for elasto-plastic heterogeneous materials subjected to random cyclic and nonproportional loading paths. Computer Methods in Applied Mechanics and Engineering 369 (2020)

[2] C. Furtado, L.F. Pereira, R.P. Tavares, M. Salgado, F. Otero, G. Catalanotti, A. Arteiro, M.A. Bessa, and P.P. Camanho, A methodology to generate design allowables of composite laminates using machine learning, International Journal of Solids and Structures, 233, 2021.

[3] L. Wu, L. Adam and L.Noels, Micro-mechanics and data-driven based reduced order models for multi-scale analyses of woven composites. Composite Structures, 2021

[4] A. Quintanas-Corominas, P. Maimí, E. Casoni, A. Turon, J. A. Mayugo, G. Guillamet, and M. Vázquez, A 3D transversally isotropic constitutive model for advanced composites implemented in a high-performance computing code, European Journal of Mechanics - A/Solids, 71, 2018

[5] P. Beaucaire, T. Benamara, R. Chocat, L. Debeugny, C. Sainvitu, P. Breitkopf, and E. Wyart, Uncertainty propagation for reliability analysis by combining regression and classification surrogates WCCM-ECCMAS 2020, January 11-15, 2021, Paris, France

[6] A. Parmentier and D. Dumas, Numerical predictions of the cure-induced deformations of composite parts manufactured using closed mould processes, In 12th International Conference on Composite Science and Technology (ICCST12), 8-10 May 2019, Sorrento, Italy

Travelling Wave Actuation on a Morphing Wing Prototype of A3xx Type for Aerodynamic Performance Increase by Means of Numerical Simulation

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Keywords: Smoothed traveling wave, morphing wing, shear layer manipulation

This study aims at investigating the flow around a morphing wing [1] at Reynolds number of 1 Million and angle of attack of 10° in low subsonic regime corresponding to take-off conditions. A separation of the boundary layer occurs at approximately 80% of the chord towards the trailing-edge (Fig. 3). Formation of strong shearing downstream leads to the development of Kelvin-Helmholtz vortices and farther downstream, to von Kármán vortex shedding. An increase of drag can be observed in such configurations.

A new concept is under development based on morphing using an innovative interface with a controlled Smoothed Traveling Wave "STW" implemented over a specifically optimised zone of the wing's suction side (Fig. 1a), covering an optimal distance from the trailing edge. The objective is to implement and validate the STW in the Navier-Stokes Multi-Block "NSMB" solver and to analyse the role of the different related parameters such as the zone's length and disposition, the wavelength, the amplitude of deformation and the frequency of the Travelling Wave (TW). A large parametric study has been carried out to detect optimal ranges for the aerodynamic performance increase. These parameters will be used afterwards in an experimental study on a morphing wing prototype where the travelling wave can be materialised through novel piezo-actuators composed of PVDF and CNT (Carbon-NanoTubes), to achieve suitable deformations. The SWT interacts with the separation of the boundary layer as well as with the coherent and surrounding turbulence vortices in the wake (Fig. 2) and produces highly impacting *feedback effects* on the overall wall pressure distribution, thus giving, for an optimal set of the TW parameters, *a high Lift-to-drag performance reaching **13%** (fig. 1a).* This result is beyond current performances offered by other systems in the state-of-the-art.

Thanks to these optimal parameters a reduction of the separation area can be achieved and a *manipulation* of the shear-layer and von Kármán vortices in the wake, producing the afore mentioned benefits. In Fig.1b is shown a significant reduction of principal frequency bumps and of the overall spectral energy thanks to the morphing, through pressure transducer measurements at 80% of the chord, indicating noise reduction obtained.

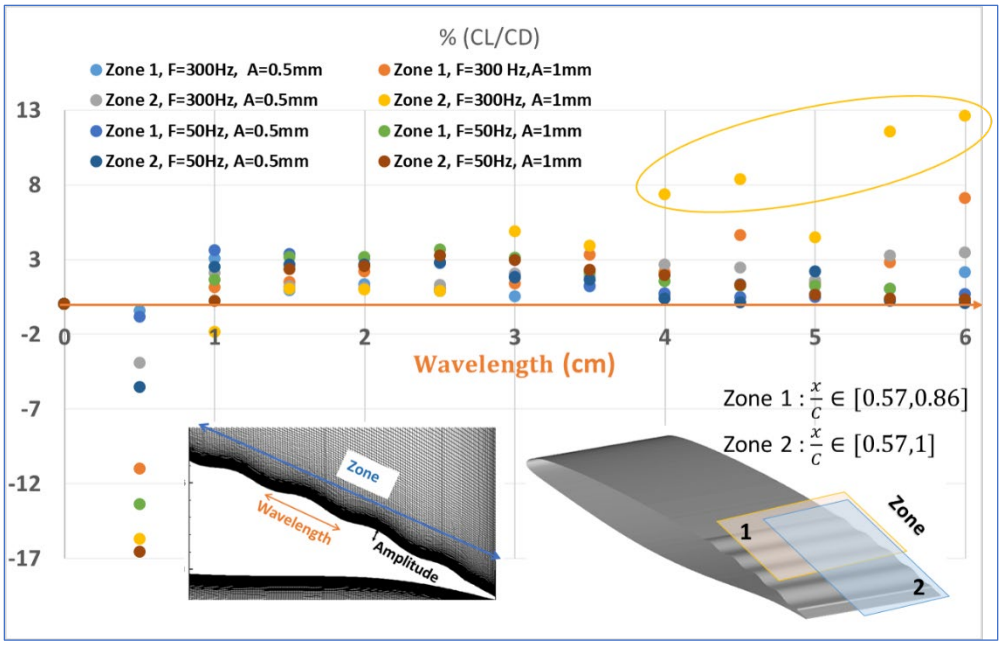

Fig. 1a. Lift - to Drag gain/loss percentage comparing to the non-morphing (static) case through Hi-Fi simulations by means of the NSMB code, carried out by IMFT and UNISTRA/ICUBE Laboratories, obtained from the effects of a travelling wave over a specific zone along the chord and the span. The figure shows gains reaching **13%** of performance increase. Re=1 million, angle of incidence 10°, A320 wing of 70 cm chord and 68 cm span, incidence of 10° and Reynolds number of 1 million.

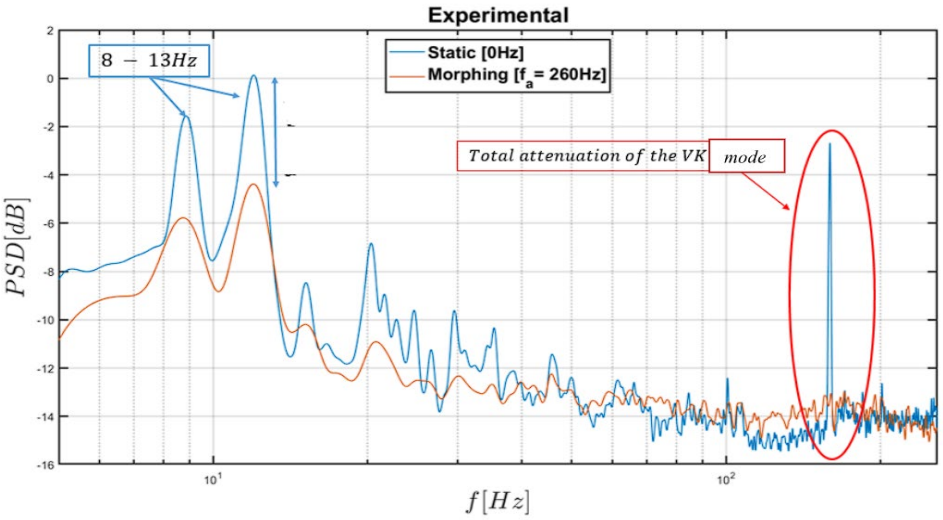

Fig. 1b. Experimental wall pressure Power Spectral Density (PSD) in dB at a measurment point located at medium span at 80% of the chord, showing reduction of the spectral energy obtained by morphing through ones eries of MFC mini-piezoactuators disposed along the span and a total attenuation of the Von Kármán mode.

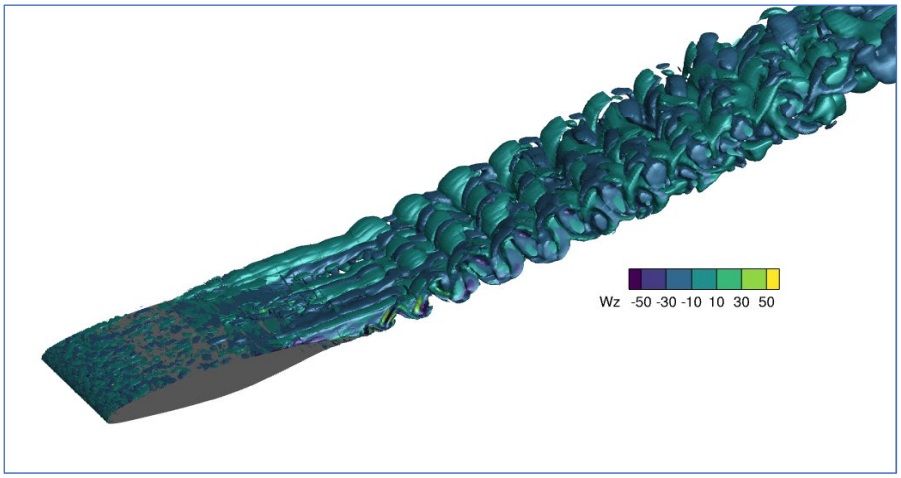

Fig. 2 Isovorticity contours illustrating the vortical structures manipulated through the Travelling Wave (TW) morphing.

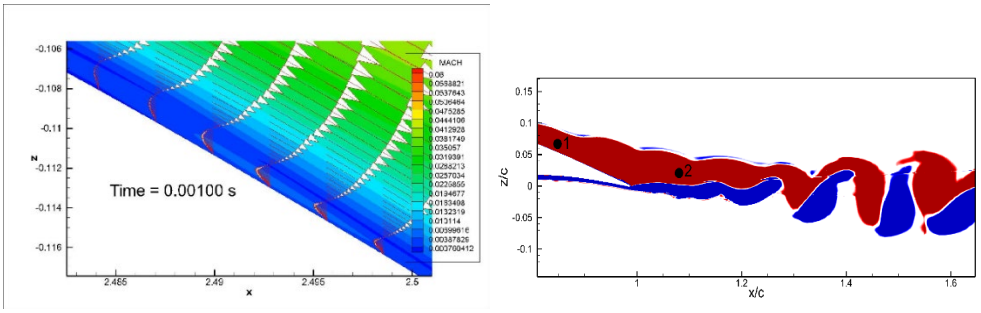

Fig. 3: (left) Separation of the boundary layer and recirculation of the flow, (right) von Kármán vortex shedding in the wake in the static (non-morphing) configuration.

References

[1] N. Simiriotis, G. Jodin, A. Marouf, P. Elyakime, Y. Hoarau, J.C.R. Hunt, J.F. Rouchon, M. Braza, Morphing of a supercritical wing by means of trailing edge deformation and vibration at high Reynolds numbers: Experimental and numerical investigation, J. of Fluids and Structures, https://doi.org/10.1016/j.jfluidstructs.2019.06.016

MS-2 – Numerical Methods and Applications

Chair: Nico Gauger

Speakers:

Bishwesvar P. Singh, University of Turku:
Empirical Analysis of Different Hybridization Strategies for Solving Systems of Nonlinear Equations

Sandro Lancellotti, University of Turin:
On the Interpolation Vertex-Related Communities for the Partition of Unity on Graphs

Christian Peco, Penn State University:
Biomimetic Coordination and Optimization Models for Transport Networks

Benet Eiximeno Franch, Barcelona Supercomputing Center:
On Data Driven Reduced Order Models for the Automotive Industry

Jari Korpela, University of Jyväskylä:
Predicting Air Traffic Schedule Changes with Artificial Intelligence

Empirical Analysis of Different Hybridization Strategies for Solving Systems of Nonlinear Equations

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Keywords: Hybridization, nonlinear optimization, numerical methods

We consider a system of nonlinear equations

$$F(x) = \begin{pmatrix} F_1(x) \\ F_2(x) \\ \vdots \\ F_m(x) \end{pmatrix} = 0 \tag{1}$$

where $F_1, F_2, \ldots, F_m: \mathbb{R}^n \to \mathbb{R}$ are nonlinear and twice continuously differentiable functions. Many optimization-based methods (e.g. [1, 2]) have been developed for solving (1). In an optimizationbased approach, constraint satisfaction problem (1) can be reformulated as an optimization problem

$$\min_{\mathbf{x}\in\mathbb{R}^n} f(\mathbf{x}) := \min_{\mathbf{x}\in\mathbb{R}^n} \frac{1}{2}\|\mathbf{F}(\mathbf{x})\|^2 \tag{2}$$

where $\|\cdot\|$ means Euclidean norm. If the minimum of (2) exists with $f(x) = 0$, then it corresponds to the solution of (1).

Inspired by the combination methodology presented in [3], we consider eight various hybridization strategies for solving a system of nonlinear equations (1). Extensive numerical experiments performed on a selected set of test problems confirm the fact that the hybridization of the conjugate gradient algorithm with Newton's method outperforms other hybrid methods considered.

In the hybrid algorithm Newton's method is supposed to increase the convergence rate and the conjugate gradient method is supposed to follow the orthogonality of the residuals and conjugacy of the search directions. Taken in combination, methods try to discover global optima and keep computer memory requirements relatively low. We also perform ranking analysis which provides some flexible choices in hybridization strategies for decision-makers based on their individual preferences and biases. In addition, using the Wilcoxon signed-rank test we confirm that in almost all cases considered in our computational experiments, the hybridization strategies demonstrate a statistically significant difference in produced results.

In future research, we consider the possibility of generalizing the hybrid methods for the case of nonsmooth analysis [4]. Possible applications can be found in the field of image processing (e.g. point pattern matching) and robotics (e.g. inverse kinematics for robotic manipulators) [5].

References

[1] F. Aragón, M. Goberna, M. López, M. Rodríguez: Nonlinear Optimization, Springer, 2019.
[2] Y. Shi: Globally convergent algorithms for unconstrained optimization, Computational Optimization and Applications, 2000, vol. 16, pp. 295-308.
[3] S. Taheri, M. Mammadov: Solving systems of nonlinear equations using a globally convergent optimization algorithm, Global Journal of Technology & Optim., 2012, vol. 3, pp. 132-138.
[4] A. Bagirov, N. Karmitsa, M.M. Mäkelä: Introduction to Nonsmooth Optimization: Theory, Practice and Software, Springer, 2014.
[5] A. Antoniou, W. Lu: Practical Optimization: Applications of Unconstrained Optimization, Springer, 2007.

On the Interpolation Vertex-Related Communities for the Partition of Unity on Graphs

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Keywords: Partition of unity methods, kernel-based approximation, binded communities detection, graph signal processing, data-driven computing

The growing popularity of graphs as a tool for representing spatial data has made it possible to view the classical problem of scattered data interpolation as a signal interpolation problem on graphs [3]. When the amount of data increases, the computational expense could be prohibitive and the partition of unity method (PUM) became an effective way to face the problem, see [1]. More precisely, in this context, we consider approximation methods based on local generalized translates of a graph basis function (GBF) [2], thus giving rise to a GBF-PUM scheme. Then, we propose a divisive-aggregative algorithm to generate the partition of unity cover through the evaluation of centrality measures and modularity of the interpolation vertices as well as the graph structure itself. Numerical results support our study and show how the method behaves on a road network.

References

[1] R. Cavoretto, A. De Rossi and W. Erb. Partition of unity methods for signal processing on graphs. Journal of Fourier Analysis and Applications, 27:1–26, Art. 66, 2021.
[2] W. Erb, Graph signal interpolation with positive definite graph basis functions. Applied and Computational Harmonic Analysis, 60:368–395, 2022.
[3] L. Stanković, L. Daković and E. Sejdić, Introduction to graph signal processing. In L. Stanković, E.Sejdić, editors, Vertex-Frequency Analysis of Graph Signals, Springer, Cham, pages 3--108, 2019.

Biomimetic Coordination and Optimization Models for Transport Networks

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Keywords: Network, bio-inspired, optimization, computational mechanics, finite elements

Solving high-combinatorial problems and achieving complex adaptive behavior in transport networks can be challenging through conventional engineering top-down approaches. In this work, we draw inspiration from biological bottom-up approaches, based on the concept of emergence, and explore how the computational modeling of network forming organisms in nature can change our perspective in optimization problems. Slime molds constitute fascinating models for emergence; formed by aggregation of almost identical cells, their internal networks optimize transport better than engineers, solve mazes, detect masses at a distance, or memorize periodic events.

We establish here a theoretical and computational framework to explain, quantify and reproduce how the nonlinear interactions between geometry, mechanical features, and environment, determines an emergent coordinated transport network morphology. These networks have the ability to expand, survive, or disappear in the presence of different media stimuli. We propose a phase-field scalar variable to represent the network matrix evolution, and a diffusive-advective process for the information transport. This framework enables high fidelity simulations of biological networks in the three-dimensional space, which are challenging due to the coupled physics involved, high-order partial differential equations, and the existence of a highly complex evolving geometry. We then propose a path based on graph neural networks to translate the new transport paradigms to small swarms of robots that develop transport networks that maximize efficiency and robustness. The emergent properties of these organisms are similar in nature to general transport networks, and we can exploit them to design interactive networks, self-healing materials, or even coordinate aerial drone swarms.

References

[1] Ghanbari, F. Costanzo, F. Hughes, D. P. and Peco, C., Phase-field modeling of constrained interactive fungal networks. Journal of the Mechanics and Physics of Solids, 45, 104160, 2020.

[2] Sgarrella, J., Ghanbari, F. and Peco, C., I-STL2MOOSE: From STL data to integrated volumetrical meshes for MOOSE. SoftwareX, 21, 101273, 2023.

On Data Driven Reduced Order Models for the Automotive Industry

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Keywords: Reduced order models (ROM), automotive industry

The present work exploits the benefits of applying the proper orthogonal decomposition (POD) [1] and dynamic mode decomposition (DMD) [2] to wall-modelled LES simulations of the yawed windsor body at $\delta = 2.5°$ and $Re = 2.9 \times 10^6$. The computational grid has a total amount of 41.42 million grid points, the turbulence is treated using the Vreman model [3] and the near wall region is modelled with the Reichardt wall law with an exchange location method in the fourth node [4]. The database for the ROM analysis is formed by 569 snapshots which extend over a period of $t = 21.2$ TU.

Amongst other benefits as the coherent structures' identification and storage space reduction, the usage of ROMs has helped to capture back-pressure changes with the yaw angle, to create an interpolation model that allows to compute the mean base pressure between $\delta = 2.5°$ and $\delta = 10°$. The results are especially satisfactory for $\delta = 5°$, with a mean error of $\varepsilon = 5.35\,\%$.

Acknowledgements This work was partially supported by Ministerio de Economía y Competitividad, Secretaría de Estado de Investigación, Desarrollo e Innovación, Spain (ref. PID2020-116937RB-C21 and PID2020-116937RB-C22).

References

[1] J. L. Lumley. Rational approach to relations between motions of differing scales in turbulent flows. Physics of Fluids, 10(7):1405, 1981.

[2] P J Schmid. Dynamic mode decomposition of numerical and experimental data. Journal of Fluid Mechanics, 656:5–28, 2010.

[3] AW Vreman. An eddy-viscosity subgrid-scale model for turbulent shear flow: Algebraic theory and applications. Physics of Fluids, 16(10):3670–3681, 2004.

[4] O Lehmkuhl, GI Park, ST Bose, and P Moin. Large eddy simulation of practical aeronautical flows at stall conditions. In Proceedings of the 2018 Summer Program, Stanford University, pages 87–96, 2018.

Predicting Air Traffic Schedule Changes with Artificial Intelligence

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Keywords: Air traffic, schedule, predicting, machine learning, artificial intelligence

Air transport differs from other forms of public transport in terms of speed and for the concentration of their contact networks. Activities related to the airport and environmental factors affect to the total time used for the planned schedule. The forecasted schedule tells deviations and delays, leaving stakeholders time to react to the changed schedules.

The research method was Design Science with three-loop model. The forecasting algorithm was a step-by-step method of machine learning (XGBoost). The aim of the research was to develop a forecasting model that predicts a roundtrip flight schedule the day before the flight with an accuracy of five minutes.

The overall forecast was made by combining the partial forecasts made from the different phases of the flight. The phases were: turning time, taxiing time to the runway, route flight and taxiing to the gate of the arrival station. Forecasting in phases enabled optimization of input variables for each phase and validating and correcting each phase to fit the objective before combining the phases. Instead of delays, the duration of each phase of the flight was predicted, which after overall duration forecast was created for the forecasted schedule.

The data is about flights between Helsinki and Oulu over a year-long period. The flight data contained 9,400 flights, of which 6,045 were flights between Oulu and Helsinki (540 km). The traffic volume data contained 8,512 rows of information about traffic at Helsinki airport.

There were 17,473 weather reports from Helsinki–Vantaa airport and 17,391 from Oulu airport. Each weather report was enriched to 55 data columns. Data of the headwinds were collected from Jyväskylä and Oulu areas (FL340 and FL180). There were a total of 22,560 lines of upperwind information.

Fig. 1 shows the total time and forecast from the Helsinki departure gate back to Helsinki arrival gate. The time in question includes nine forecasts for the roundtrip HEL-OUL-HEL. The accuracy of roundtrip forecast using the test data was four minutes five seconds. The correlation was 0.927. This meets well the set five-minute accuracy requirement. So it is possible to predict the roundtrip flight schedule with the required accuracy using machine learning methods if used weather forecasts are accurate.

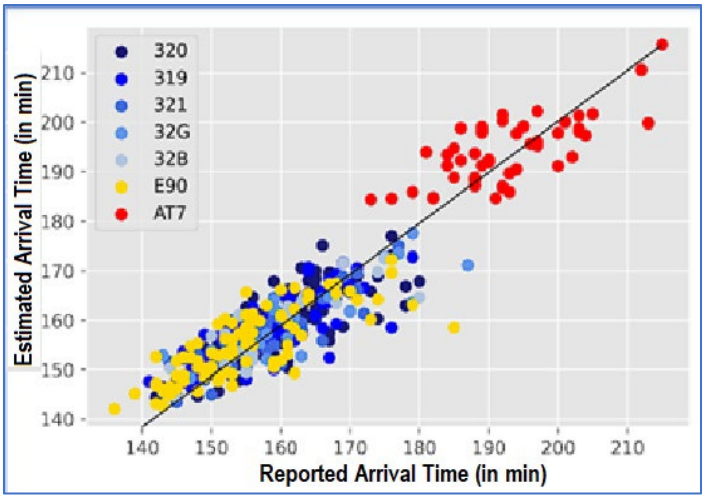

Fig. 1 Total time and forecast from the Helsinki departure gate back to Helsinki arrival gate

Also better forecasts for arrival times can be achieved. Fig. 2 shows the estimated arrival time deviation from the actual arrival time by flights arriving to Helsinki (blue line). The mean error of the estimate is 4.7 minutes. The mean error of the estimate by the research is only 1.2 minutes (red line). The research predicts a four times more accurate estimate for arrival times.

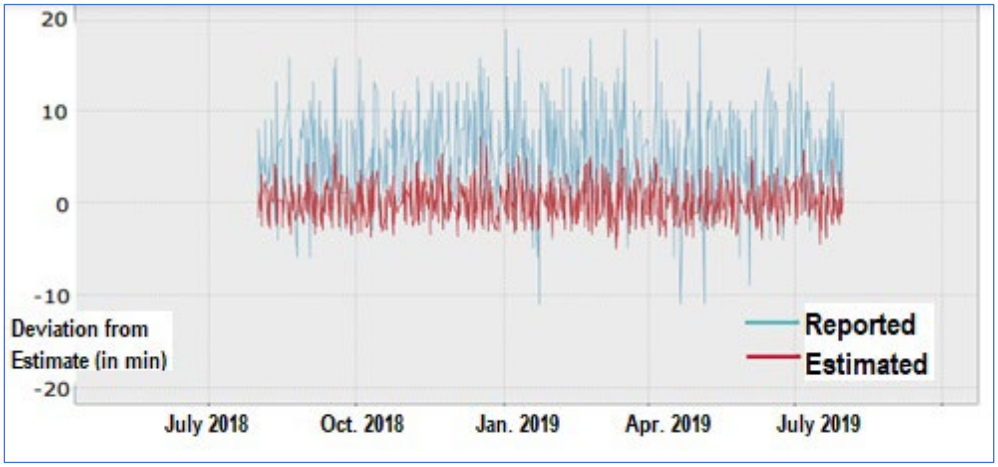

Fig. 2 Estimated arrival time deviation from the actual arrival time by flights arriving to Helsinki

A similar kind of prediction model had not been previously studied. With the knowledge learned and by refining the goal, forecasting models for unique needs can be made. The multi-stage model allows the final application to be made so that as the phases of the flight progress or as the time of departure approaches, the final result can be refined. The inputs become more accurate as the forecast period shortens. In addition, it is possible to change inputs (aircraft type and departure/arrival port) and so influence the predicted results.

MS-3 – EU-funded Research in Transport: Surface Transport

Chair: Dietrich Knoerzer

Speakers:

Maurizio Maggiore, EC, DG RTD – Future Urban & Mobility Systems:
Modelling and Simulation for the Transition to Zero Emissions Transport in EU-Funded Partnerships

Lokukaluge Prasad Perera, UiT - The Arctic Univ. of Norway:
Advanced Data Analytics Based Digital Twin Technology for Green Technology Integration in Shipping

Ahmet Gurkan, The University of Strathclyde, Glasgow:
The First Retrofit Application of the Gate Rudder System on a Coastal Cargo Vessel

Bill Karakostas, Inlecom Systems, Brussels:
Knowledge Graph Based Digital Twin to Support Green Shipping

Hoss Habib, Keyward GmbH, Berlin:
Revolutionizing Vehicle Design: Machine Learning for External Vehicle Aerodynamics

Modelling and Simulation for the Transition to Zero Emissions Transport in EU-Funded Partnerships

Maurizio Maggiore

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Keywords: Zero emission road transport, European partnerships, digital twins, AI

The European Commission research and development funding has supported for a long time the development of software solutions to speed up the uptake of zero-emissions solutions by facilitating the development of modelling tools on a par with those available for conventional cars.

European Partnerships as the Partnerships for Batteries (BATT4EU) and the Partnership Towards Zero Emission Road Transport (2Zero) are co-programmed partnerships funded under the Horizon Europe programme and aiming at accelerating the transition towards zero exhaust emission road mobility across Europe. They and their predecessors are instrumental in developing the needed tools under a holistic industry-led approach. Projects from previous EU Framework Programmes will be presented, as well as running ones and topics for future calls in this domain, opening the way to a pervasive use of digital twins, multi scale modelling and AI in automotive and battery design and development in order to reach the holy grail of software-defined electric vehicles.

Advanced Data Analytics Based Digital Twin Technology for Green Technology Integration in Shipping

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Keywords: Digital twin, green technology, marine engines, dynamic wing, maritime, shipping, emission reduction, energy efficiency

Novel green technologies should be adopted by the shipping industry to cope with the rules and regulations that are and will be enforced in the near future by the maritime authorities to make zero-emission vessels. The near and mid-term carbon-intensive rules and regulations can be illustrated as the reduction of at least 40% CO2 emissions by 2030 with the continuation of 70% CO2 emissions by 2050. To achieve such ambitious emission reduction targets, the shipping industry should be facilitated with appropriate energy efficiency and emission reduction technologies. The SeaTech (Next Generation Short-sea Ship Dual-Fuel Engine and Propulsion Retrofit Technologies) H2020 project has proposed two symbiotic ship engine and propulsion innovations that can be utilized towards achieving the proposed emission reduction target by increasing the vessel fuel efficiency by 30%, while reducing the emissions of CO2 46%, NOx 99%, SOx 99%, and particulate matter 94%. The SeaTech engine innovation consists of an ultra-high energy conversion dual-fuel engine supported by a precisely controlled combustion process to reduce emissions. The SeaTech renewable-energy-based propulsion innovation consists of a ship bow-mounted bio-mimetic dynamic wing capturing wave energy in moderate and higher sea states, creating extra propulsion thrust to reduce engine power and damping undesirable ship motions.

However, the proposed two symbiotic ship engine and propulsion innovations have not been implemented in an ocean-going vessel during this project period, but those innovations have been evaluated under prototype demonstrations in a relevant environment. The SeaTech engine has been developed and demonstrated under the Wartsila engine testing facility, where the respective data sets to quantify the same technology have been collected. The bow-mounted bio-mimetic dynamic wing has been developed and demonstrated under the vessel testing facility of the National Technical University of Athens (NTUA), similarly the respective data sets to quantify the same technology have been collected. Since these technologies have not been evaluated as integrated technologies in an ocean-going vessel, the data sets collected from the SeaTech engine and propulsion innovations are used in a data science environment to combine their performances. The proposed data science environment consists of an advanced data analytics framework (ADAF) to quantify the SeaTech engine and propulsion innovations with respect to expected ship energy efficiency and emission reduction requirements while satisfying the relevant KPIs (key performance indicators) in this project.

The advanced data analytics developed under this project will also be utilized towards developing a digital twin integrated with life cycle cost analysis (LCCA) for a selected ocean-going vessel to integrate the SeaTech engine and propulsion innovations and quantify the vessel performance improvements and understand economical viability with respect to the existing technologies. Therefore, the respective ship owners can make optimal decisions on the proposed innovations by retrofitting for their existing fleets and/or integrating for their newbuild vessels, by not only considering their fleet improvements in energy efficiency and emission reduction but also under their economical viability of a return on investment, i.e. can be approximately 400% due to fuel and operational cost savings.

The First Retrofit Application of the Gate Rudder System on a Coastal Cargo Vessel

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Keywords: Retrofitting, gate rudder system, power and fuel saving, GHG emission, manoeuvrability, underwater radiated noise

The ongoing H2020 Project GATERS [1, 2] aims to exploit the application of a novel propulsive energy-saving and manoeuvring device called Gate Rudder System (GRS) that provides a sound base for the most attractive power-saving hence reduced emission option. The further advantage of the GRS is the provision of highly effective manoeuvrability within coastal areas and ports and more efficient and safer navigation in waves during oceangoing operations. However, there is no current application of the GRS as a "retrofit"; hence, it was proposed in GATERS as its primary aim. The project also aims to develop and demonstrate to TRL 6 an innovative, cost-effective retrofit solution for maritime shipping, substantially improving environmental impacts and life cycle costs.

This presentation reports on the latest progress in GATERS, starting with developing comprehensive empirical, computational, and experimental design tools and their applications for designing the first retrofit GRS on the 90m coastal cargo carrier MV ERGE. This follows by reviewing the manufactured GRS components and their retrofitting process on MV ERGE at the drydock. The presentation also summarises the dedicated sea trials with MV ERGE with her conventional rudder system (CRS) in January 2023. The subsequent sea trials with the retrofitted GRS are scheduled for mid-April 2023, followed by long-term performance monitoring.

So far, our predictions showed the powering benefits for the MV ERGE over 10% at the design speed of 12 knots on full-scale. This could be doubled in waves due to the increasing thrust on the GR blades as opposed to the growing resistance of the conventional rudder. The manoeuvring predictions for MV ERGE demonstrated superior performance at low speed with its natural ability for crabbing, reduced over-shooting angles, and quicker turning speeds. Also, the cavitation tests revealed the benefits of lowering the URN levels (15dB). However, comparing the full-scale trial data before and after the retrofitting of GRS will provide the ultimate assessment of the GRS for MV ERGE to achieve the main objectives of the GATERS project as the next task in the project agenda.

References

[1] GATERS Partners and INEA, 2020. "GATERS-H2020-MG-2018-2019-2020 / H2020-MG-2019-TwoStages – No: 860337". The European Commission.
[2] https://www.gatersproject.com/

Knowledge Graph Based Digital Twin to Support Green Shipping

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Keywords: Digital twin, green shipping, knowledge graph

This paper will describe ongoing work carried out in the context of the DT4GS (Digital Twins for Green Shipping) EU Horizon funded project. In DT4GS, digital twins are utilised in the context of supporting the decarbonization of the shipping sector through new green ship designs and the retrofitting of the existing fleet with green technologies. The knowledge graph connects concepts and instances from heterogeneous domains pertaining to green shipping technologies and hosts black box (pure data based), grey box and physics-based ship models. Moreover, interoperability between models and data from different technical domains including cross-domain simulations, and 'what if' scenario analysis is supported.

In this paper we will discuss how the knowledge graph supports the intelligent exploration of alternative green ship designs and decarbonisation technologies and their trade-offs in terms of emissions, costs, and other relevant technical and socioeconomic parameters.

Revolutionizing Vehicle Design: Machine Learning for External Vehicle Aerodynamics

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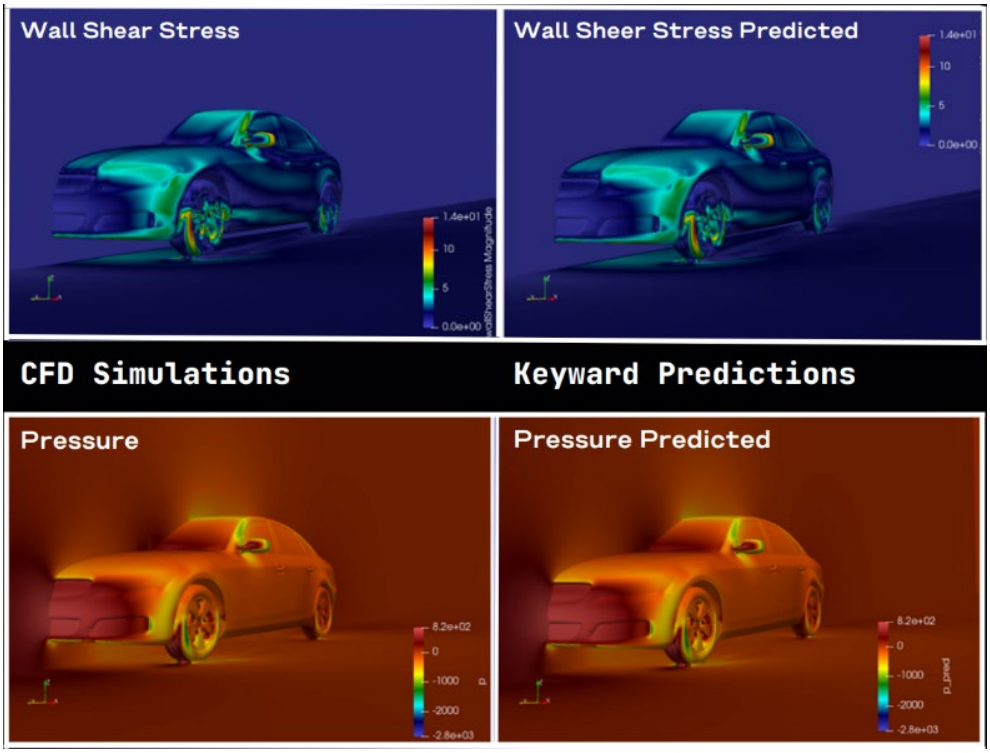
Keywords: Machine learning, engineering design, CFD simulation, generative design, Saas

During a typical development cycle in the automotive industry, a multitude of design iterations are performed in order to improve external aerodynamic performance while preserving the desired vehicle aesthetics. This iterative process has an inherent bottleneck at the evaluation step where CFD analysis needs to be performed. A typical steady-state analysis of the vehicle design can take somewhere between several hours to several days. This puts a hard limitation on a designer's and engineer's ability to explore a broader design space required for optimal aerodynamic performance. Reduced Order Models (ROMs) are powerful tools that have been increasingly used in engineering and science. One of the main advantages of using ROMs is the significant reduction in simulation and computing costs. Instead of running expensive simulations for every design configuration, engineers can train a ROM using a carefully selected data set and then use the ROM to predict flow behaviour for a wide range of design configurations. To showcase the capabilities of this approach, Keyward has developed a ROM (POD + Kriging) for a steady-state analysis of the DrivAer model. To that end, a set of three parameters were defined on the baseline geometry of the DrivAer model. Initially, 15 steady-state simulations were performed for different combinations of the chosen parameters. The generated batch of data was then analysed using Keyward’s data analytics tools with the goal to identify a set of 15 additional parameter combinations. This step ensures an optimal distribution of the Design of Experiments (DOE) for the chosen domain space. The ROM was trained on data generated from 30 simulations to predict all relevant flow properties, including velocity field, pressure field, and wall shear stress on the vehicle's outer surface. The training of the model took 4,5 hours on an AWS G4 instance.

The trained model was then integrated, as a plugin, into Paraview, a common engineering software. Users can specify input parameters for the ROM model over the interface and get a prediction in less than 1 second. By leveraging post-processing capabilities of Paraview, this integration enables users to seamlessly visualise and analyse predicted flow properties in a familiar environment. To validate the ROM's accuracy, a separate test set of 20 new geometry variations was created. This set consists of designs that hadn't been present in the training data, thereby allowing Keyward to test generalisation capabilities of the model over the desired domain space. In this test case, the only parameter that varied was the front bumper height of the vehicle. The average delta in drag between CFD and Keyward results is 0.0028 with a minimum delta of 0.0002 and a maximum delta of 0.0076. The accuracy of the prediction is strongly correlated with the density of the training data distribution.


Wall Shear Stress
Wall Sheer Stress Predicted
CFD Simulations
Keyward Predictions
Pressure
Pressure Predicted

MS-4 – Applications of Advanced Computational Methods

Chair: Ilkka Pölönen

Speakers:

Leevi Lind, University of Jyväskylä:
Predicting Near-Earth Asteroid Surface Temperature Distribution from Spacecraft-Based Near-Infrared Spectra Using a Neural Network

Salli Pääkkönen, University of Jyväskylä:
Non-invasive Monitoring of Microalgae Cultivations in Laboratory Scale Using Hyperspectral Imager

Anna-Maria Raita-Hakola, University of Jyväskylä:
FireMan - Early Detection and Observation of Forest Fires

Kimmo Riihiaho, University of Jyväskylä:
Hyperspectrical Vegetation Simulation from Leaves to Canopies

Vilho Halonen, University of Jyväskylä:
Quantifying Errors Caused by Uncertain Data in Partial Differential Equations Using Neural Networks

Predicting Near-Earth Asteroid Surface Temperature Distribution from Spacecraft-Based Near-Infrared Spectra Using a Neural Network

Leevi Lind

University of Jyväskylä, Jyväskylä, Finland

Keywords: Spacecraft, neural network, spacecraft-based near-infrared spectra

Asteroids can tell us about the birth of our solar system, but they may also become an important industrial resource in the future. Both goals require spacecraft missions to asteroids to learn more about them, and these could be made much more affordable by using small spacecraft such as CubeSats. A small platform has limited volume and electrical power available for instruments, highlighting the importance of distilling as much knowledge as one can from the limited data. To this end, we have developed a neural network for estimating surface temperature maps of near-Earth asteroids from spacecraft-based near-infrared (NIR) spectra. The efficiency of the method makes it a candidate for data processing performed on the spacecraft's on-board computer, taking a step towards autonomous asteroid missions.

Non-invasive Monitoring of Microalgae Cultivations in Laboratory Scale Using Hyperspectral Imager

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Keywords: Microalgae cultivation, neural network, spectral imager, green fuel

High expectations are placed on microalgae as a raw material to replace fossil fuels and petrochemical products. Robust methods to control microalgae cultivation processes are needed to enhance efficiency and reliability of the processes. The growth of laboratory scale cultivations of three microalgae species was monitored with a spectral imager and reference methods in three separate experimental series to test vegetation index- and a one-dimensional convolutional neural network (1D CNN) based calibration models to resolve biomass from spectral images. The mean absolute percentage error (MAPE) for index-based model was 15–24% (SD = 13–18) for the different species, and for 1D CNN 11–26% (SD = 10–22). The spectral imager-based monitoring method described here is promising due to its non-invasive nature. Simultaneous use of the different models could be recommended to ensure robustness and generalizability of the monitoring pipeline.

FireMan - Early Detection and Observation of Forest Fires

Anna-Maria Raita-Hakola

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Keywords: Forest fires observation, neural networks, UAV-based observation

This presentation gives insider information about how are observed, and what are the current state-of-the-art approaches. Our research focuses on Boreal forests, aiming to develop neural network-based methods for real-time UAV-based observation and detection. As an outcome, we will now learn how fire behaves in the forests and see the current status of our ongoing project.

Hyperspectrical Vegetation Simulation from Leaves to Canopies

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Keywords: Vegetation simulation, spectral images, machine learning

Plant's growth and development can be negatively affected by biotic or abiotic stress factors. Hyperspectral imaging can be used to detect plant condition, but analysis of remotely sensed spectral images relies largely on machine learning (ML) algorithms. Training the algorithms requires a lot of training data, which is difficult to obtain. We have developed HyperBlend vegetation simulator to alleviate the data-availability problem. We are currently giving final touches to tree and forest geometry construction.

Quantifying Errors Caused by Uncertain Data in Partial Differential Equations using Neural Networks

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Keywords: Uncertainty, Monte-Carlo sampling, neural networks

Uncertain data in mathematical models causes an indeterminacy in the solutions of a model. This uncertainty error can be dealt with using probabilistic methods which involve Monte-Carlo sampling from the uncertain parameters to generate a set of different possible solutions and finding interesting quantities like average values and maximum deviations. This is computationally expensive since each sample involves solving the mathematical model. The goal of the research is to create neural networks which skip solving the mathematical model and instead directly output the error quantities of interest. This has so far been done for a simple ordinary differential equation and the Poisson equation with good results.

Plenary Session 3

Chair: Jacques Periaux

Speaker:

Sami Äyrämö, University of Jyväskylä:
Machine Learning Based Promotion of Health and Wellbeing

Machine Learning Based Promotion of Health and Wellbeing

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Keywords: Machine learning in health, medicine, relevant training data

Although the method has become state-of-the-art in medicine, success cannot always be guaranteed, and the performance of the models depends on several factors. In the absence of prior knowledge, the performance of the models is highly dependent on a sufficient amount of relevant training data as well as consistent ground truth data. Moreover, generalizable and valid results require proper processes that do not allow data leakage and produce reliable estimates of the generalization ability. In this talk, successes and failures in using machine learning in health and medicine are presented and discussed.

Special Technology Session (STS-1) - iADDVA

Chair: Matti Kurki

Speakers:

Matti Kurki, Jamk - University of Applied Sciences:
Special Technological Session iADDVA - Adding Value by Creative Industry Platform Investments

Janne Sundelin, Jamk - University of Applied Sciences:
LPBF Metal Printing Experiences and Material Test Results

Esa Alakoski, Jamk - University of Applied Sciences:
Suitability of ALD for Improving the Barrier Properties of Fiber-Based Substrate Materials

Timo Harju, Business Jyväskylä:
ADDVA Ecosystem in Jyväskylä, Experiences in Industry-City-University Co-Operations

Sami Kinnunen, University of Jyväskylä:
ALD CoCampus and Next Steps in University of Jyväskylä Research Environment Development

Kati Valpe-Ojala, Jamk - University of Applied Sciences:
Tailored AI Training for Companies – Lesson Learnt from aiADDVA ESF Project

Special Technological Session iADDVA – Adding Value by Creative Industry Platform Investments

Matti Kurki

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Keywords: RDI platform, additive manufacturing, artificial intelligence, atomic layer deposition (ALD)

The aim of the iADDVA project is to develop an RDI platform that will help the industrial and business field in Central Finland move towards the Industry 5.0 ecosystem concept. Central to today's industrial operations are creating the most efficient added value to existing products, systems and services. The project will focus on concrete actions to turn added value into a systematic process. The presentations in this session are describing parts of different areas developed in the iADDVA project including novel material technology advancements but also the new insights to the utilization of the AI (artificial intelligence). The AI will play crucial role in the success of the SME in the future and therefore right education and training for those will benefit the Industry 5.0 environment and SME internationalization.

Acknowledgement IADDVA project is funded by European Regionals Development Fund (ERDF) Leverage from the EU 2014-2020.

LPBF Metal Printing Experiences and Material Test Results

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Keywords: 3D printing, LPBF, mechanical testing

The presentation discusses the key findings and experiences obtained in 3D printing trials and subsequent material level testing in WP3 of iADDVA project. The objective was to study the effect of laser powder bed fusion (LPBF) process parameters and variables on the mechanical properties of printed parts. Two materials were included in the tests, stainless steel 316L and Inconel 718. Properties of the materials were studied with static mechanical testing, i.e. hardness measurements and tensile tests, and dynamic mechanical testing, i.e. fatigue tests.

The static mechanical test results proved that printing orientation has significant effect on tensile strength, yield strength and elongation, due to anisotropy of microstructure formed during LPBF process. On the other hand, the condition of printer air filter or printing pattern were not observed to have notable effect on mechanical properties of printed parts.

In the fatigue tests of 316L stainless steel, heating of test samples was observed. This was due to high frequency (70Hz) in the resonance frequency-based test system, which caused test bar to heat due to internal friction. In order to avoid the test bar heating, a cooling unit was developed and integrated into the fatigue test system. In addition, mechanical arrangements for reducing test frequency were taken place.

All in all, the LPBF metal printing trials and subsequent material testing performed in WP3 of iADDVA project provided valuable knowledge, which enables more efficient usage of LPBF metal printing, and strength vs. ductility optimization of the printed parts. In addition, mechanical testing capability was improved based on the observed phenomena and experiences received during the project.

Suitability of ALD for Improving the Barrier Properties of Fiber-Based Substrate Materials

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Keywords: ALD, barriers, paper, board, fibers

Atomic Layer Deposition (ALD) is the superior method for producing uniform coatings on porous substrates. The coatings are conformal and can be deposited with nanometer scale thickness control. Even a very thin ALD film (> 10 nm) can be pin-hole free. ALD coatings are thus attractive for many applications, e.g., for improvement of barrier properties of materials.

In this study thin layers of amorphous Al_2O_3 (~50 nm for measurements, ~100 nm for imaging) was deposited on several types of papers/boards with ALD. The samples were studied with Helium Ion Microscope (HIM) and Water Vapor (WVTR) and Oxygen Transmission (OTR) measurements.

The hygroscopicity of the paper/board substrates is problematic as ALD is a vacuum coating method, P_{dep}~ 1 mbar and requires an elevated temperature, T_{dep}~ 90°C. These conditions lead to a moisture desorption-absorption cycle and corresponding volume changes of the samples in vacuum and off vacuum. Further complication is the temperature coefficient mismatch between ALD coating and the substrate. As evidenced by HIM images, the conditions may lead to crack formation on the thin Al_2O_3 coating. ALD films are conformal, and it is cumbersome to fill-out pores with ALD. For fill-out, thickness of the ALD layer must at least be in the same order of magnitude as the pore diameter of substrate paper.

To conclude, thin ALD (Al_2O_3) coatings have evident potential to work as barrier improving layers on fiber-based substrates. However, a smooth intermediate base coating is an essential requirement. The material properties (e.g., elastic modulus, hardness, roughness) of the base coating must tailored so that crack formation and propagation on the ALD layer is prevented.

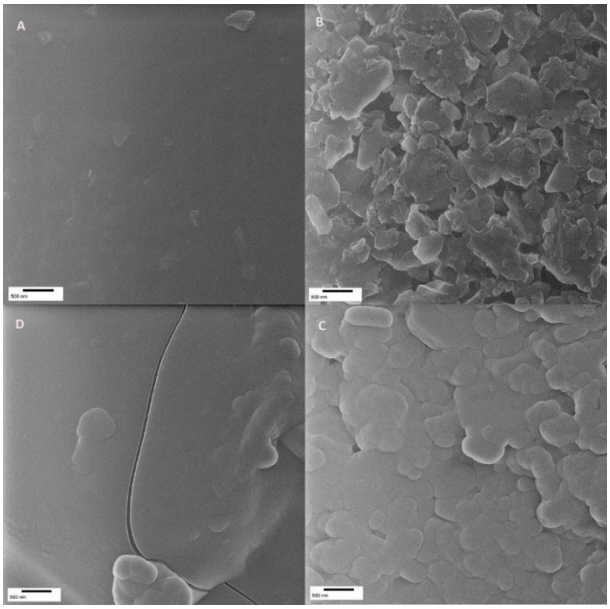

Fig. 1: HIM images A:" Smooth" base coating on a board sample, no ALD B: "Rough" base coating on a board sample, no ALD C: 100 nm ALD (Al2O3) coating on a "rough" base D: 100 nm ALD (Al2O3) coating on a "smooth" base, a crack is visible. Image area of frames is 5 µm x 5 µm.

ADDVA Ecosystem in Jyväskylä: Experiences in Industry-City-University Co-operations

Timo Harju

Business Jyväskylä, Jyväskylä, Finland

Keywords: iADDVA, ADDVA, ecosystem, industrial renewal, co-operation, R&D

This session will explore and summarize findings and experiences from ecosystem-focused co-development efforts in the city of Jyväskylä. The intention is to expose the starting points for the public-private partnership and to highlight the results from the efforts centered around the industrial renewal and ADDVA ecosystem. Thus, the session will highlight the challenges with and benefits from working across and between organizational boundaries. Such co-operation includes sharing goals and resources across organizations, engaging both the public and private sectors in co-development efforts.

Both within and parallel to the iADDVA project, Business Jyväskylä has explored ways to maximize the impact of regional development by mapping out industrial companies' needs and capability for R&D co-operation. At the same time, the project has sought to understand and develop models of co-operation within local networks and ecosystems. As a general finding we can state that while it seems obvious that co-operation acrossa organizational lines yields significant benefits, matching business and technology needs with existing R&D infrastructure and capabilities requires notable effort from both sides (or a mediator/facilitator).

ALD CoCampus and Next Steps in JYU Research Environment Development

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Keywords: Atomic layer deposition (ALD), thin film characterization

Atomic layer deposition (ALD) is the fastest growing thin film deposition technique enabling highly controlled film growth. The main user of ALD has clearly been the semiconductor industry but the number of applications outside semicon is rapidly growing. In order to boost this development in Central Finland a joint consortium ALD CoCampus with JYU and JAMK as partners was formed. ALD Co Campus acts as a contact place for industry and research institutes, and it can offer wide range research and pilot production services.

In this presentation the ALD CoCampus concept will be introduced, several already completed studies and applications will be presented, and future steps in the development of the research environment in Jyväskylä will be outlined.

Tailored AI Training for Companies - Lesson Learnt from a iADDVA ESF Project

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Keywords: Artificial intelligence (AI), train the trainer, training, coaching, manufacturing industry

In this presentation we will talk about aiADDVA - Adding value by Artificial Intelligence -project and show how we offer targeted AI training in rural areas. aiADDVA offers tailored training focused on artificial intelligence aimed particularly at SMEs in the manufacturing industry and their personnel in Central Finland. The AI training provides practical information on the opportunities brought by artificial intelligence and its limitations. An important part of the training is raising the participants' awareness of how AI can be applied in their company.

The project contributes to the Survival Plan for Central Finland and the regional programme by preventing the skills gap of SMEs and experts in the region and improving growth and competitiveness through an AI-focused training programme. The training also aims to tackle the plight of manufacturing firms in the corona pandemic by increasing their knowledge capital and improving the employability of their staff. The training will be provided by Jamk University of Applied Sciences and JYU University of Jyväskylä.

The project is connected to the ecosystem agreement between the City of Jyväskylä and the Ministry of Economic Affairs and Employment, which aims to build an ADDVA RDI environment in the area to meet the needs of the industry renewal. The project is part of a wider ADDVA for manufacturing industry in Central Finland. The project will promote the level and applicability of digital skills in the environment and is part of the implementation of the region's survival strategy.

The project will build and pilot a coaching program. The coaching includes open MOOC (Massive Open Online Course) online courses and related self-study material, provided by JYU University of Jyväskylä. And a coaching pathway, group, and Train the trainer -coaching provided by Jamk - University of Applied Sciences. The coaching will be delivered in a multi-disciplinary way.

Coaching will provide practical information on the potential of AI and its limitations. An important part of the training will also be to improve participants' understanding of the methods for applying AI in manufacturing industry. After the training, participants will understand the key concepts and methodologies related to AI, its main challenges, and potentials, and will be able to apply what they have learned in practice.

Acknowledgement The aiADDVA-project is funded by European Social Fund (ESF).

Special Technology Session (STS-2) - coADDVA

Chair: Ari Kuisma

Speakers:

Ari Kuisma, Jamk - University of Applied Sciences:
Adding Value by Computing in Manufacturing

Samppa Alanen and Tomi Nieminen, Jamk - University of Applied Sciences:
Applying Machine Learning and Computer Vision in the Quality Control of Small Objects

Juha Jeronen, Jamk - University of Applied Sciences:
Accelerated Thermomechanical Modeling of Additive Manufacturing Using Laser-Based Powder Bed Fusion

Pyry Kotilainen, University of Jyväskylä:
On Practical Implementation of Machine Learning for Microcontrollers

Adding Value by Computing in Manufacturing

Ari Kuisma

Jamk – University of Applied Sciences, Jyväskylä, Finland

Keywords: Machine vision, machine learning, artificial intelligence

The presentations in this track relate to the research results of the coADDVA project so far. A common theme of the project has been the utilization of computation in the development of production.

The aim of the project is to support companies especially in utilizing digitalisation with the help of machine vision and modern artificial intelligence solutions. In this way, various SMEs and large manufacturing companies located in the Central Finland region will receive support and a competitive advantage for growth after the corona pandemic from the results of the project.

During the project, several pilots have been carried out for the companies involved in the project, where their real production development needs have been solved with the help of calculations. In this track, we will present, for example, solutions for quality control of small metal pieces, modeling of 3D printing and accelerating computing with the help of artificial intelligence, and practical implementation of machine learning for microcontrollers.

Applying Machine Learning and Computer Vision in the Quality Control of Small Objects

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Keywords: Machine learning, deep learning, computer vision, quality control

Today quality control is still manual work in many production lines. The manufactured products need to be inspected, and the defective products removed from the production line. This is a tedious task, and the factory defects are often di-cult to detect. Small metal objects, in particular, are challenging to process in large quantity.

In the coADDVA project, we explored the automatic collection of image data and trained a convolutional neural network to detect defective products with computer vision. The model was trained with bolt images, but a similar technique can be applied to other small objects as well. We developed a sorting machine, which consists of an imaging system integrated into a mechanical conveyor. Each object is photographed from 3 sides to make sure that a possible defect is visible in one of the images. In production, all 3 images are sent to the machine learning model for classification, and if a defective object is detected, it is removed from the conveyor belt with compressed air. The same equipment was also used to collect the image data for the model training. The trained model was then deployed in a Beckhoff automation system. Finally, the functionality and accuracy of this prototype system was validated.

References

[1] R. Nematulio, A. Paul, F. Saeed and W-H. Hong. Machine learningbased automated image processing for quality management in industrial Internet of Things. International Journal of Distributed Sensor Networks, 15(10):155014771988355, 2019.

[2] R. Tercan and T. Meisen. Machine learning and deep learning based predictive quality in manufacturing: a systematic review. Journal of Intelligent Manufacturing, 33:1879-1905, 2022.

Accelerated Thermomechanical Modeling of Additive Manufacturing Using Laser-Based Powder Bed Fusion

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Keywords: Additive manufacturing, simulation, reduced order modelling

Additive manufacturing opens the possibility to create optimal tools and devices in industrial manufacturing. A key aspect is that there are very few or no geometric restrictions. Particularly, the 3D printing of metals allows one to make complex, durable, custom parts. [1]

We look at the numerical modeling of 3D printing of metals in a laser-based powder bed fusion (L-PBF) printer. We take a process industry viewpoint, using the theory of axially moving materials [2]. This change of perspective, along with aggressive simplification, allows us to see fundamental features of the process itself we would otherwise miss, were we to model the printing of some specific object in detail. Particularly, with axially moving materials, we can easily look at what happens around the melt pool as the focus spot of the laser moves over the powder bed.

The simulation is based on a 2D thermomechanical continuum model, which extends the earlier 1D model reported in [3]. The model is solved numerically with the finite element method (FEM), using the FEniCS framework [4]. Each instance of the simulation requires some computing time on a conventional CPU-based multicore workstation, with MPI parallelization.

To interpolate in the solution space more quickly, we aim to accelerate repeated simulations with slightly different initial conditions or parameter values with the help of artificial intelligence (AI) techniques, namely neural networks. Particularly, deep neural networks [5] have become popular in AI during the last decade as hardware has become more powerful.

In an engineering sciences context, deep neural networks can be used for dimension reduction, producing a reduced model that runs much faster, while retaining most of the fidelity of the original. A particularly promising class of deep neural networks for this application are continuous latent space models, such as variational autoencoders (VAE) [6].

References

[1] J. O. Milewski. Additive Manufacturing of Metals. Springer, 2017, Springer Series in Materials Science, vol. 258. doi.org/10.1007/978-3-319-58205-4

[2] N. Banichuk, A. Barsuk, J. Jeronen, P. Neittaanmäki, and T. Tuovinen. Stability of Axially Moving Materials. Springer, 2020, Solid Mechanics and Its Applications, vol. 259. doi.org/10.1007/978-3-030-23803-2

[3] J. Jeronen, T. Tuovinen, and M. Kurki. One-dimensional thermomechanical model for additive manufacturing using laser-based powder bed fusion. Computation, 10(6), 83, 2022. doi.org/10.3390/computation10060083
[4] A. Logg, K.-A. Mardal, G. N. Wells et al. Automated Solution of Differential Equations by the Finite Element Method. Springer, 2012, doi.org/10.1007/978-3-642-23099-8
[5] I. Goodfellow, Y. Bengio, and A. Courville. Deep Learning. MIT Press, 2016, www.deeplearningbook.org
[6] D. P. Kingma and M. Welling. An Introduction to Variational Autoencoders. 2019. arxiv.org/abs/1906.02691

On Practical Implementation of Machine Learning for Microcontrollers

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Keywords: Tiny machine learning, deep learning, anomaly detection

The recent progress in development of low-budget sensors and single-board computers has enabled deploying artificial intelligence (AI) on the edge which in turn allows service providers to deliver reduced latency, efficient bandwidth consumption, improved data security, increased privacy, and lower costs. Tiny machine learning (ML) models implemented on such smart devices can be used for object recognition [1] and time-series classification [2]. Furthermore, increasing computing and connectivity capabilities of modern microprocessors has made it possible to deploy tiny AI/ML models not only for inference but also for training [3].

In this study, we focus on implementation and evaluation of supervised and unsupervised machine learning models which can be deployed and trained on tiny smart devices for classification, regression, and anomaly detection. We conduct our experiments in the context of three following use cases: wind speed estimation and anomalous vibration detection and classification. First, we study various traditional and neural network based ML methods which can be employed to solve the problems formulated under low computing and memory resource constraints. These include but are not limited to various deep learning architectures [4], decision tree ensembles [5] and stream clustering algorithms [6]. Next, we discuss techniques and tools which can be used to implement these algorithms on single-board devices. These for example involve automatic machine learning optimization to produce maximum performance from learning tools without human assistance [7]. Finally, several of the most efficient machine learning algorithms found are implemented on multiple modern microcontrollers and evaluated in terms of prediction error, classification accuracy, inference time and other metrics.

References

[1] Estrebou CA, Fleming M, Saavedra MD, Adra F, De Giusti AE. Lightweight Convolutional Neural Networks Framework for Really Small TinyML Devices. In: SmartTech-IC. Springer. 2022; pp. 3–16.

[2] Gupta S, Jain S, Roy B, Deb A. A TinyML Approach to Human Activity Recognition. In: Journal of Physics: Conference Series, vol. 2273. IOP Publishing. 2022; p. 012025.

[3] Ren H, Anicic D, Runkler TA. Tinyol: Tinyml with online-learning on microcontrollers. In: IJCNN. IEEE. 2021; pp. 1–8.

[4] Ruff L, Vandermeulen R, Goernitz N, Deecke L, Siddiqui SA, Binder A, Müller E, Kloft M. Deep one-class classification. In: ICML. PMLR. 2018; pp. 4393–4402.
[5] Friedman JH. Stochastic gradient boosting. Computational statistics & data analysis. 2002; 38(4):367–378.
[6] Silva JA, Faria ER, Barros RC, Hruschka ER, Carvalho ACd, Gama J. Data stream clustering: A survey. ACM Computing Surveys (CSUR). 2013;46(1):1–31.
[7] Jin H, Song Q, Hu X. Auto-keras: An efficient neural architecture search system. In: Proceedings of the 25th ACM SIGKDD international conference on knowledge discovery & data mining. 2019; pp. 1946–1956.

Programme

Monday, 15 May 2023		
Time and Place	**Activity**	**Presenter**
8:00	**Registration at Agora main lobby**	
9:00 **Agora:** **Gamma**	**Opening Ceremony**	Chair: Tero Tuovinen
	Welcome by the Host University of Jyväskylä	Lauri Kettunen, University of Jyväskylä
	Introduction in the CM3 - Transport Conference 2023	Pekka Neittaanmäki, University of Jyväskylä
	Jacques Periaux - A Commitment to Science and its Industrial Applications Personal Message of Pierre Perrier to the 80th Anniversary of Jacques Periaux	Olivier Pironneau, Academy of Sciences of France
	Plenary Session 1	Chair: Pekka Neittaanmäki
	Enabling Technologies for Predictive Digital Twins	Trond Kvamsdal, SINTEF and NTNU
	Efficient Industrial Aerodynamic Shape Optimization by Combining Sobolev Methods with Arbitrary Parameterizations	Nicolas Gauger, Technical University of Kaiserslautern
10:45	***Coffee Break***	
11:15 **Agora:** **Gamma**	**Anniversary Session 1 for Jacques Periaux – Different Applications of Optimization Tools**	Chair: Trond Kvamsdal
	Advective Diffusive Models for the Spread of Infectious Disease	William E. Fitzgibbon, University of Houston
	Combining Pareto Optimality with Nash Games in Multi-Objective Prioritized Optimization of an Aircraft Flight Performance	Jean-Antoine Desideri, INRIA
	A Natural Evolution-Based Approach to Aerodynamic Shape Design: From Early Experiments with Airfoils to Multi-Objective and Robust Optimization	Domenico Quagliarella, Italian Aerospace Research Centre (CIRA)
12:15	***Lunch Break***	

Monday, 15 May 2023		
13:15 **Agora:** **Gamma**	**Anniversary Session 2 for Jacques Periaux – Advanced Methods in Optimizations**	Chair: William Fitzgibbon
	1993–2023 – 30 Years of Evolution in Design Optimization	Carlo Poloni, ESTECO
	25 Years in Design Optimisation - an Evolution of Methods	Boris Naujoks, TH Köln – University of Applied Sciences
	Enhancing Computational Engineering through Game Theory Based Evolutionary Algorithms and Machine Learning	David Greiner, University of Las Palmas de Gran Canaria
	Variational Study of Mesh and Shape Optimization	Alain Dervieux, INRIA
	34 Years of European Research Cooperation on Computational Methods in Aeronautics	Dietrich Knoerzer, Aeronautics Consultant
14:55	***Coffee Break + Group Picture in Agora Lobby***	
15:25 **Agora:** **Gamma**	**Anniversary Session 3 for Jacques Periaux – Messages from all over the World**	Chair: Carlo Poloni
	Causal Inference for Power Grid Dynamics	Hiroshi Suito, Tohoku University
	A personal message to Jacques Periaux	Eugenio Oñate, CIMNE/UPC
	PPLTMG – A Parallel Adaptive Method	Randolph Bank, UC San Diego, USA
	An Interpretation of China's Actions for Global Climate-Neutral Aviation	ZHANG Shukun, JI Yuhan and BAI Wen, Chinese Aeronautical Establishment
	Joint Exploration in the Endless Frontiers of MDO	Zhili Tang, Nanjing University of Aeronautics & Astronautics
	Optimisation in Aerospace and Biomedical Engineering	Srinivas Karkenahalli, University of Sydney
	Closing words by Jacques Periaux	
17:30	***End of Day 1***	
17:30 - 18:30	***Welcome Reception at Hotel Alba, next to Agora Mattilanniemi***	

Tuesday, 16 May 2023					
Time and Place	**Activity**			**Presenter**	
9:15 Agora: Alfa	**Plenary Session 2**			Chair: Jacques Periaux	
	Hybrid Rapid Aerodynamic Modelling at Airbus			Xavier Bertrand, Airbus	
	Radiative Transfer for Atmospheres with Clouds			Olivier Pironneau, Academy of Sciences of France	
10:45	***Coffee Break***				
11:15 Agora: Alfa	**Session on Applications of Computational Methods**			Chair: Olivier Pironneau	
	Digital Aircraft Design with Carbon Fiber Reinforced Thermoplastics			Yoshiaki Abe, Tohoku University	
	Uncertainty Quantification based on Multifidelity Metamodels and Reduced Order Models			Alberto Clarich, ESTECO	
	Multi-objective Green Delivery Routing with Flexible Time Windows: Minimizing Fossile Fuel Consumption vs. Maximizing Quality of Service			Michael Emmerich, Leiden University	
12:15	***Lunch Break***				
Time and Place	**Activity**	**Presenter**	**Time and Place**	**Activity**	**Presenter**
13:15 Agora: Alfa	**MS-1 – EU-funded Research in Transport: Aviation Transport**	Chair: Dietrich Knoerzer	**13.15 Agora: Gamma**	**MS-2 – Numerical Methods and Applications**	Chair: Nico Gauger
	EU-Funded Research and Innovation towards Greener and Digital Transport	Leonidas Siozos-Rousoulis, EC, CINEA		Empirical Analysis of Different Hybridization Strategies for Solving Systems of Nonlinear Equations	Bishwesvar P. Singh, University of Turku
	An Overview of Jet-Airframe Interaction Noise Research in the DJINN Project	Daniel Lindblad, Imperial College London		On the Interpolation Vertex-Related Communities for the Partition of Unity on Graphs	Sandro Lancellotti, University of Turin

Tuesday, 16 May 2023					
	ESATTO - A Holistic Multi-Disciplinary Framework for Future Supersonic Aviation	Grazia Piccirillo, Polytechnic University of Turin		Biomimetic Coordination and Optimization Models for Transport Networks	Christian Peco, Penn State University
	Design Strategies Using Hybrid Models for Manufacturing and Vulnerability of Composite Structures	David Dumas, CENAERO		On Data Driven Reduced Order Models for the Automotive Industry	Benet Eiximeno Franch, Barcelona Supercomputing Center
	Travelling Wave Actuation on a Morphing Wing Prototype of A3xx Type for Aerodynamic Performance Increase by Means of Numerical Simulation	Rajaa El Akoury, IMFT Toulouse		Predicting Air Traffic Schedule Changes with Artificial Intelligence	Jari Korpela, University of Jyväskylä
14:55	***Coffee Break***				
15:25 **Agora:** **Alfa**	**MS-3 – EU-funded Research in Transport: Surface Transport**	Chair: Dietrich Knoerzer	**15.25** **Agora:** **Gamma**	**MS-4 – Applications of Advanced Computational Methods**	Chair: Ilkka Pölönen
	Modelling and Simulation for the Transition to Zero Emissions Transport in EU-Funded Partnerships	Maurizio Maggiore, EC, DG RTD – Future Urban & Mobility Systems		Predicting Near-Earth Asteroid Surface Temperature Distribution from Spacecraft-Based Near-Infrared Spectra Using a Neural Network	Leevi Lind, University of Jyväskylä

Tuesday, 16 May 2023					
	Advanced Data Analytics Based Digital Twin Technology for Green Technology Integration in Shipping	Lokukaluge Prasad Perera, UiT The Arctic University of Norway		Non-invasive Monitoring of Microalgae Cultivations in Laboratory Scale Using Hyperspectral Imager	Salli Pääkkönen, University of Jyväskylä
	The First Retrofit Application of the Gate Rudder System on a Coastal Cargo Vessel	Ahmet Gurkan, University of Strathclyde		FireMan - early detection and observation of forest fires	Anna-Maria Raita-Hakola, University of Jyväskylä
	Knowledge Graph Based Digital Twin to Support Green Shipping	Bill Karakostas, City, Inlecom Systems, Brussels		Hyperspectrical Vegetation Simulation from Leaves to Canopies	Kimmo Riihiaho, University of Jyväskylä
	Revolutionizing Vehicle Design: Machine Learning for External Vehicle Aerodynamics	Hoss Habib, Keyward GmbH, Berlin		Quantifying Errors Caused by Uncertain Data in PDE's using Neural Networks	Vilho Halonen, University of Jyväskylä
17:05	***End of Day 2***				
19:00 - 22:00	***Conference Dinner at Sataman Viilu, Satamakatu 10, 40100 Jyväskylä***				

Wednesday, 17 May 2023		
Time and Place	**Activity**	**Presenter**
9:15 **Agora:** **Alfa**	**Plenary Session 3**	Chair: Jacques Periaux
	Machine Learning Based Promotion of Health and Wellbeing	Sami Äyrämö, University of Jyväskylä
10.00	***5 min Break***	
10:05 **Agora:** **Alfa**	**Special Technology Session (STS-1) - iADDVA**	Chair: Matti Kurki
	Special Technological Session iADDVA - Adding Value by Creative Industry Platform Investments	Matti Kurki, Jamk - Univ. of Appl. Sciences
	LPBF Metal Printing Experiences and Material Test Results	Janne Sundelin, Jamk - Univ. of Appl. Sciences
	Suitability of ALD for improving the barrier properties of fiber-based substrate materials	Esa Alakoski, Jamk - Univ. of Appl. Sciences
11:05	***Coffee Break***	
11:30 **Agora:** **Alfa**	**Special Technology Session (STS-1) - iADDVA**	Chair: Matti Kurki
	ADDVA ecosystem in Jyväskylä, experiences in industry-city-university co-operations	Timo Harju, Business Jyväskylä
	ALD CoCampus and next steps in University of Jyväskylä research environment development	Sami Kinnunen, University of Jyväskylä
	Tailored AI Training for Companies - Lesson Learnt from aiADDVA ESF Project	Kati Valpe-Ojala, Jamk - Univ. of Appl. Sciences
12:30	***Lunch Break***	
13:30 **Agora:** **Alfa**	**Special Technology Session (STS-2) - CoADDVA**	Chair: Ari Kuisma
	Adding Value by Computing in Manufacturing	Ari Kuisma, Jamk - Univ. of Appl. Sciences
	Applying Machine Learning and Computer Vision in the Quality Control of Small Objects	Tomi Nieminen, Samppa Alanen, Jamk - Univ. of Appl. Sciences
	Accelerated Thermomechanical Modeling of Additive Manufacturing Using Laser-Based Powder Bed Fusion	Juha Jeronen, Jamk - Univ. of Appl. Sciences

Wednesday, 17 May 2023		
	On Practical Implementation of Machine Learning for Microcontrollers	Pyry Kotilainen, University of Jyväskylä
14:50	***Coffee Break***	
15:15 **Agora:** **Alfa**	**Conference Closing Session**	Chair: Dietrich Knoerzer
	Summary of the CM3 -Transport Conference, a View back and Future Perspectives	Jacques Periaux, CIMNE
	Planned Publications of the CM3 - Transport Conference 2023 within the ECCOMAS-Springer Book Series 'Computational Methods in Applied Sciences	Tero Tuovinen, Jamk - Univ. of Appl. Sciences
	Closing remarks	
15:30	***End of Day 3 and of CM3 Conference 2023***	