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Paulo R. M. Lyra & Darlan K. E. Carvalho

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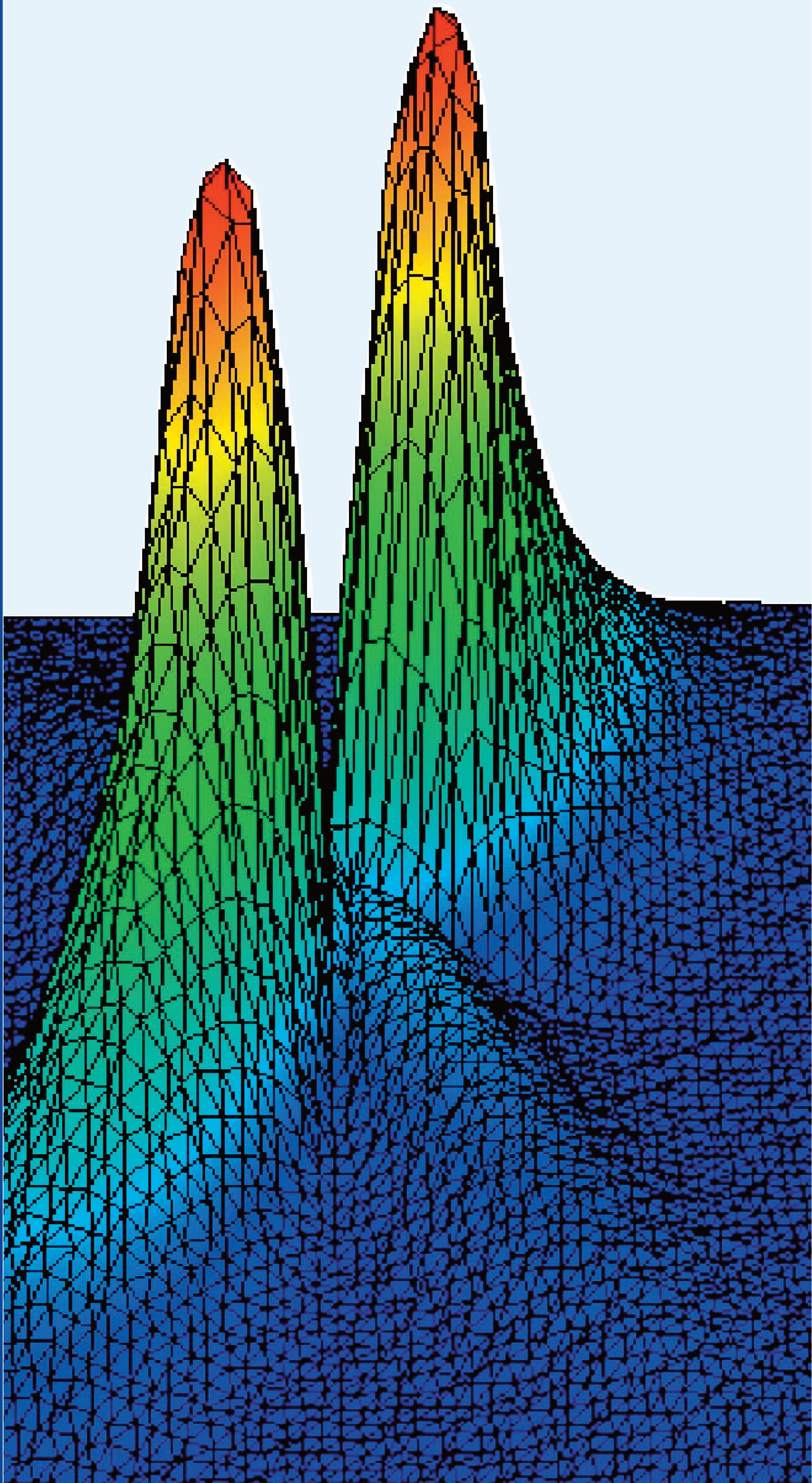

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contents

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Robust Numerical Formulations for the Simulation of Multiphase & Multicomponent Fluid Flows in Naturally Fractured, Heterogeneous & Anisotropic Porous Media Using Unstructured Meshes & Multiscale Discretizations

by
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The numerical modelling and simulation of multiphase and multicomponent flows in naturally fractured porous media, such as petroleum reservoirs, aquifers, geothermal reservoirs, etc., for different industrial and environmental applications, including oil and gas recovery, contaminant transport, geologic CO_2 sequestration, nuclear waste disposal and geothermal energy production, is a very challenging task. It involves the modelling of complex geological features such as high rock heterogeneity and anisotropy, the presence of faults, fractures (channels and barriers), pinchouts or even caves, cavities and vugs, that can be usually encountered in carbonate (karst) reservoir rocks. Besides, in many oil industry applications, it is also necessary to deal with directional and/or multilateral wells due to the necessity to avoid well surface locations that are logistically or environmentally inadequate. In addition, some problems may involve the coupling of thermal-hydro-mechanical and chemical phenomena, which ideally requires integrated modelling of reservoirs, wells and facilities, and even, the numerical simulation for multiple reservoirs. Despite the remarkable progress in this field, in the last decades, there is still a need for extensive research, ranging from the increase of physical complexity associated to the explosive growth of data from the geological characterization to the introduction of use of general and flexible unstructured meshes to cope with geometric complexity, the consideration of uncertainty propagation and the inclusion of all components of High Performance Computing (HPC) and data analytics [14; 21; 31].

In this context, ideally, several properties are desired from the numerical formulations used to discretize the PDEs that result from the mathematical modelling of these phenomena, such as: a solid theoretical foundation (e.g., stability, coercitivity, convergence and error estimates); be locally conservative and satisfy a Discrete Maximum Principle (DMP), to achieve high-order of accuracy on general unstructured and non "K-orthogonal" grids; produce solutions free of Grid Orientation Effects (GOE); lead to well-conditioned linear systems; to incorporate HPC strategies, etc. Unfortunately, currently, there is no scheme that satisfies all these properties simultaneously [16; 17].

Our research group: PADMEC (High Performance Computing on Computational Mechanics) has investigated, proposed and combined various components to develop robust, accurate and flexible reservoir simulators that can address the above challenges. In particular, here, we present some recent developments related to non-orthodox finite volume methods for the pressure equation, the use of very high order methods for the transport equation, the extension of multiscale and multilevel locally conservative methods to unstructured meshes and the modelling of multiphase and multicomponent fluid flow in heterogeneous, anisotropic and naturally fractured reservoirs.

Non-Orthodox Finite Volume Methods for the Pressure Equation

Among the locally mass conservative linear schemes typically used in the petroleum reservoir simulation for the discretization of the Darcy flux, we can mention the Mixed Finite Element (MFE) method [14], the Mimmetic Finite Difference (MFD) [19], the Discontinuous Galerkin (DG) method [27] and the Multipoint Flux Approximation (MPFA) finite volume schemes [1; 10]. In this context, we should refer to a class of recently developed non-orthodox MPFA schemes that have "full pressure support", such as the: MPFA-D (Diamond Stencil) [7; 11], extended for 3-D by Lira et al., 2021 [20], the MPFA-H (Harmonic Points) [2] and the MPFA-QL (Quasi-Local Stencil) [26] which are quite robust to deal with strong physical and mesh anisotropy and are able to accurately reproduce piecewise linear solutions through a linear preserving interpolation with explicit weights that avoids solving locally defined systems of equations that are typical of more classical MPFA methods such as the MPFA-O and the MPFA-FPS [1; 10]. Differences among these linear schemes range from the imposition of local continuity throughout the control surfaces, which is particularly important in the case of heterogeneous and, possibly, discontinuous permeability tensors, to the definition of the stencil used in the flux approximation. In *Figure 1*, we present the pressure field obtained with the MPFA-D formulation in a 3-D simulation, which reproduces a piecewise linear solution for a heterogeneous, and discontinuous full permeability tensor.

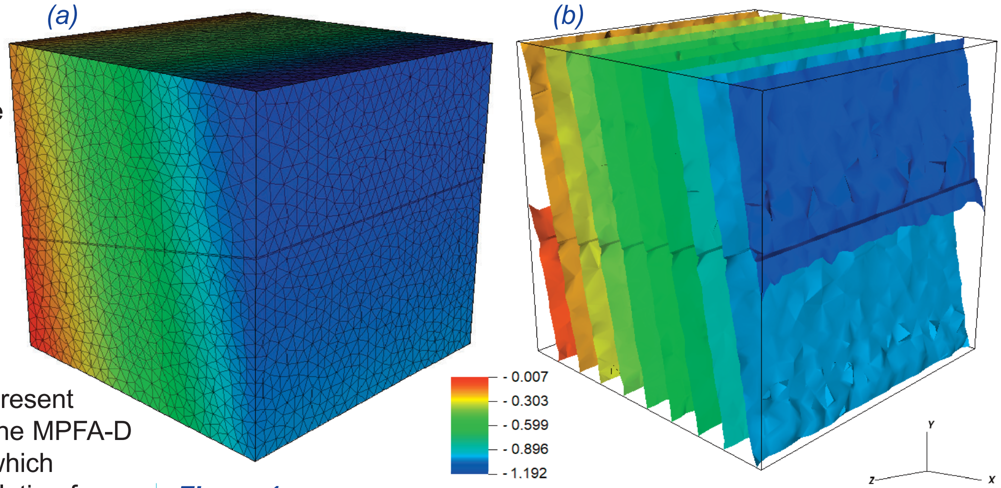


Figure 1:
The Oblique Drain test:
(a) pressure distribution; (b) isosurface contours.
Mesh size: 46,923 volumes [20].

It is well-known that no linear formulation, including the most robust GFEM, MFEM, MFD, DG and MPFA methods can guarantee satisfaction of the Discrete Maximum Principle (DMP) or at least monotone solutions for general non-orthogonal meshes or arbitrary anisotropic full permeability tensors [17] for the diffusion operator. For certain pathological cases, this fact can generate non-physical Darcy fluxes associated to spurious pressure oscillations and fictitious gas as a consequence of the pressure field falling below the bubble point in different points of the reservoir. On the other hand, nonlinear formulations can be built to satisfy the DMP or, at least, some monotonicity requirements. In this context, several nonlinear finite volume (NLFV) methods have been developed in the last two decades [8; 12; 17; 25; 32]. Usually, in these schemes, the final nonlinear algebraic system of equations is solved by the first-order Picard iteration method to guarantee monotone solutions [25]. In *Figure 2*, we can see the solution obtained by a NLFV that satisfies the DMP. Convergence history is also shown for different 2D meshes, with and without Anderson Acceleration (AA.

High-Order and Spectral Methods for the Transport Equation

In petroleum reservoir simulation, the standard method to discretize the advective terms in the transport equations is the classical First Order Upwind (FOU) method. Even though it is robust and simple to implement, it is well known that it suffers from strong artificial diffusion and Grid Orientations Effects (GOE). This latter problem, in which completely different and false solutions can be obtained by using meshes with different spatial orientations, and which is dependent of the relative direction between the multiphase fluid flow

(a) Problem definition *(b) Pressure field*

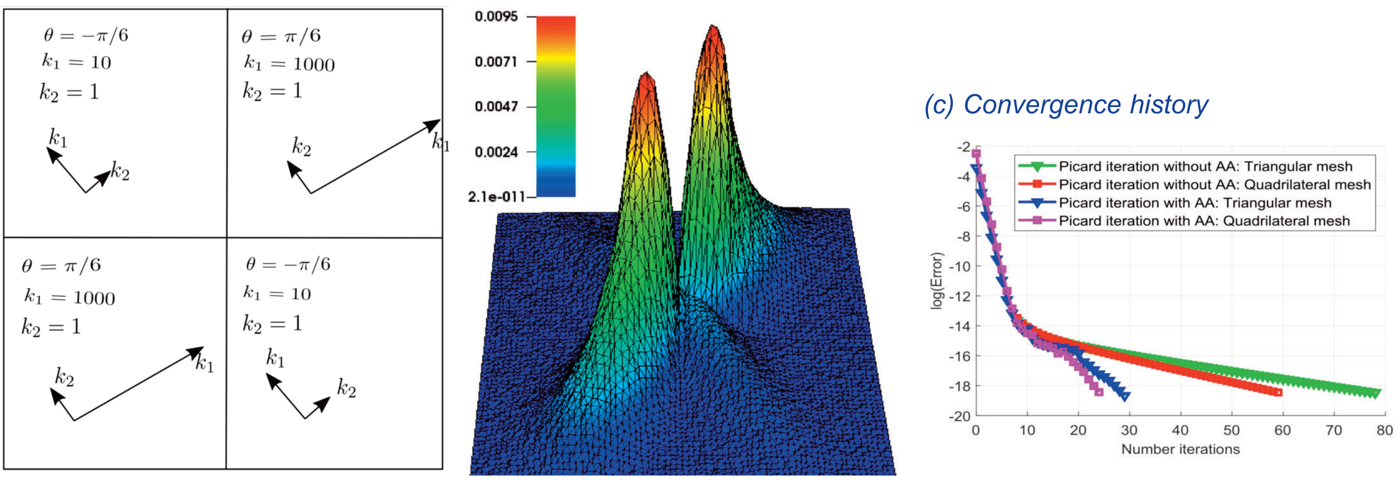


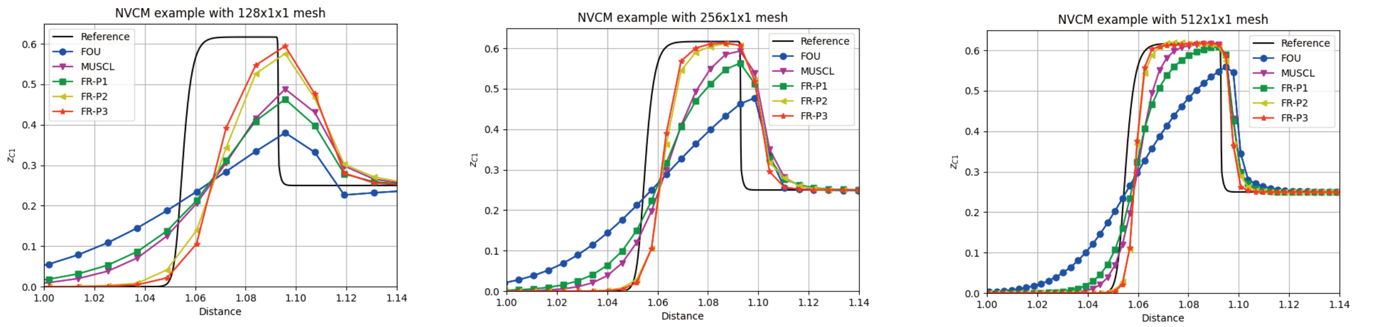
Figure 2:
NFVM solution using Picard iteration with convergence acceleration of a single-phase flow in a heterogeneous and highly anisotropic porous media [8]:
(a) Anisotropic permeability tensor; (b) Pressure solution; (c) Picard convergence history.

and the grid lines, can be extremely important, particularly for many real-world applications involving flows where the mobility of the resident fluid is much smaller than the mobility of the displacing fluid. In these cases, the so called Saffman-Taylor front instability may occur, causing a competition between non-physical viscous fingers and the diffusive effects that try to dissipate sharp fronts. These problems include miscible displacements, the recovery of heavy oils, and other Enhanced Oil Recovery Techniques (EOR), such as polymer injection, thermal recovery or the alternate injection of water and gas (Water Alternate Gas – WAG), etc. [16; 26; 29; 31].

> *"Our strategy has proven to accurately handle oil-water fluid displacements with heterogeneous and anisotropic full permeability tensors for matrix and fractures in naturally fractured reservoirs."*

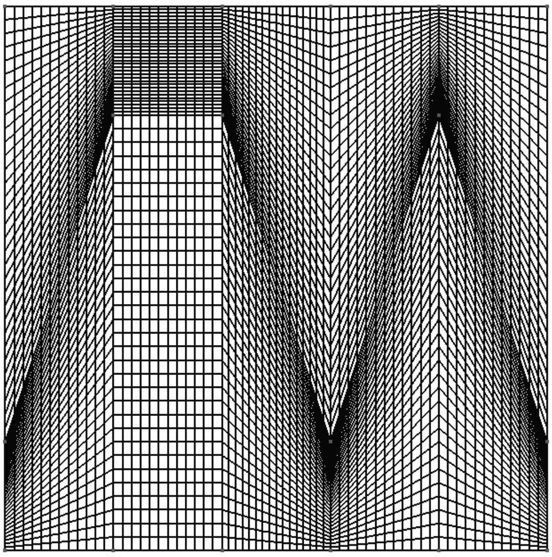
In this context, the development of high order, truly multidimensional and locally conservative formulations that can be used in general unstructured meshes is of utmost importance to reduce artificial numerical diffusion and GOE, and to improve the reliability of the approximate numerical solutions. Second order upwinding is commonly available in petroleum reservoir simulators, and 2nd order MUSCL (Monotonic Upstream-Centered Scheme for Conservation Laws) type formulations for two and three phase flow formulations [5; 22]. Usually, in these cases, the pressure-velocity problem is solved by the Control Volume Finite Element (CVFEM) formulation, MFEM (Mixed Finite Element), MPFA or NLFV methods [10; 13; 14]. However, in the context of fluid flow in heterogeneous petroleum reservoir or aquifers, higher than second order is yet to be more explored, even though some efforts can be found using k-exact formulations [35]; ENO and WENO approaches [18] and DG methods [27]. More recently, very high order (VHO) spectral formulations have been developed for 1D and 2D oil-water displacements, including the Spectral Volume (SV), Spectral Difference (SD), nodal DG and the Flux Reconstruction/Correction Procedure via Reconstruction (FR/CPR) methods [26]. These methods have shown high potential to incorporate h-p type adaptivity and handle extremely complex compositional flows in naturally fractured, heterogeneous and anisotropic porous media. In [26] we have used the MPFA-QL coupled with the FR formulation to simulate oil-water displacements in highly heterogeneous and anisotropic oil reservoirs with excellent results. In order to properly couple cell centred MPFA methods with the nodal spectral formulations, it is necessary to obtain an appropriate velocity reconstruction within the primal control volumes (CVs) of the computational mesh. This can be achieved by a reconstruction operator based in the mixed finite element basis functions of Raviart-Thomas (RT) or Brezzi-Douglas-Marini (BDM) [4]. This operator receives the input fluxes through each control surface and returns the point-wise values of the velocity field everywhere within the CV, where the saturation must be computed. In fact, a key aspect of VHO methods used for the numerical simulation of petroleum reservoirs is their low computational cost with a similar degree of accuracy when compared to their lower order counterparts.

An example retrieved from Moshiri and Manzari (2019) [22] and that consists of a multicomponent fluid flow, in which CO_2 is injected in a 1D reservoir containing C1, C4, C10 and C16 with the same molar fractions is shown in *Figure 3*. For this case, it is assumed that there is no volume change on mixing, as the components change phases and constant K-values are used. First order upwind (FOU), second order MUSCL and higher order Flux Reconstruction solutions are shown considering different levels of mesh refinement (i.e., 128, 256 and 512 Control Volumes - CVs), highlighting the improving in accuracy by both h and p mesh refinement.



(a) 128 CVs *(b) 256 CVs* *(c) 512 CVs*

Figure 3:
Grid convergence study of overall global composition of C1 throughout the domain using different levels of mesh refinement (i.e., 128, 256 and 512 Control Volumes – CVs).



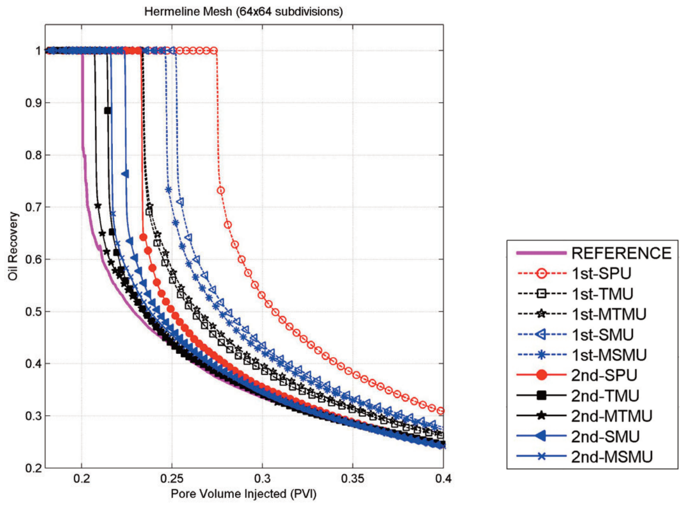
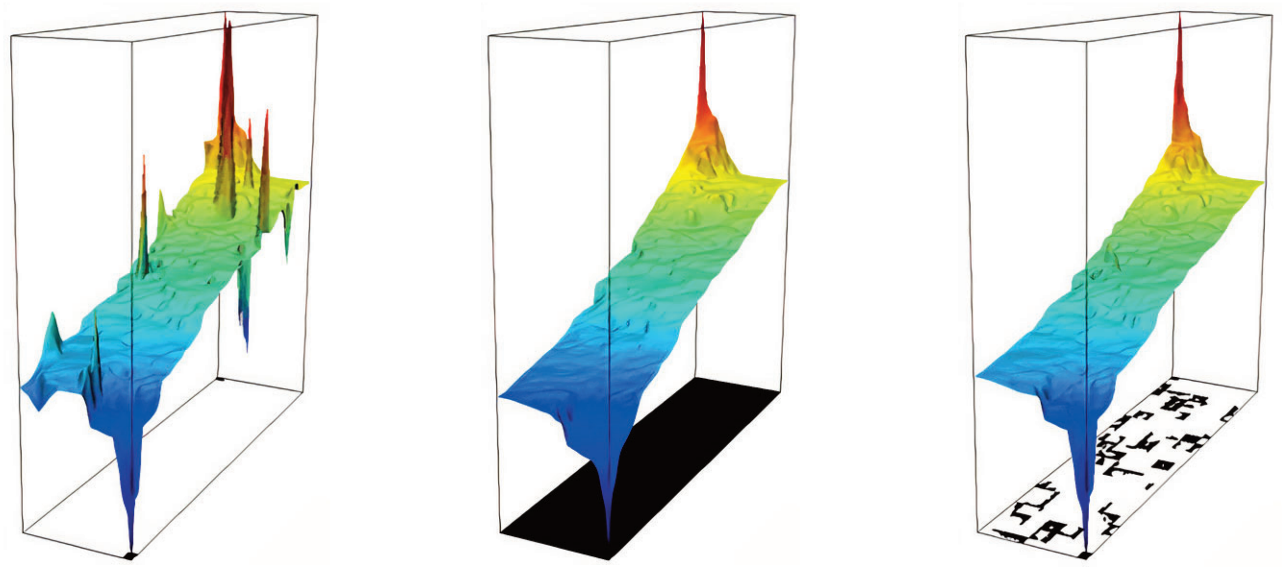


Figure 4:
Water saturation front obtained for a distorted mesh with 64 x 64 CVs, using standard first and second order upwind schemes and different multidimensional flow-oriented schemes and the reference solution using 37,996 CVs (see [35] for further details).

To further reduce GOE, truly multidimensional formulations have also been used in literature. First and second order mass weighted schemes have been originally devised for the Navier-Stokes equations in [30]. In the context of petroleum reservoir simulation, we should mention the works of Hurtado et al., 2007 [13] and Kozdon et al., 2011 [16]. More recently, explicit and implicit truly multidimensional upwinding has been proposed in the works of Souza et al., 2018 [35] and Keilegavlen et al., 2012 [16]. In [35], authors have combined a MUSCL-type method with the Multi-dimensional Limiting Process (MLP) [24]. This formulation has shown improved monotonicity properties and the ability to produce reasonable physical solutions with reduced GOE and artificial numerical dissipation, considering fluid flows with high mobility ratios and very distorted 2D unstructured meshes as it can be seen in *Figure 4*.

Multiscale-Multilevel Finite Volume Methods

With advances in geological characterisation, petrophysical models of subsurface petroleum reservoirs have been refined to a scale of orders of magnitude higher than standard petroleum reservoir simulators. The challenges associated with simulating unconventional reservoirs, such as those with highly heterogeneous and anisotropic permeability fields and their convoluted geometry, lead to simulations with ever increasing computational power. As a result, multiple simulations on the high-resolution geological scale are not feasible. The practical and most common solution to this problem is to use an upscaling technique that homogenises the petrophysical properties and thus transfers the information from the high-resolution geological and static grid to the lower-resolution simulation grid. The main disadvantage of this technique is that the high-resolution aspects of the flow are lost in this process, as the geologic information remains on the high-resolution grid. A promising solution to deal with the computational limitations and take advantage of the high-resolution scale is the use Multiscale methodologies [14; 15; 38]. The idea behind these schemes is to create a set of operators by which the system of equations of the high-resolution grid can be projected onto the space of the low-resolution grid, where it can be solved and projected back onto the high-resolution grid. In this way, it is possible to obtain a reasonably accurate approximate solution [33] at the geological scale. In the context of structured meshes, an interest approach that incorporates the concept of automatic mesh adaptation in the framework of the MsFV is the Algebraic Dynamic Multilevel (ADM) of Cusini et al., 2016 [9]. The ADM uses the MsFV multiscale operators in the simulation while maintaining some high-resolution volumes at the fine scale to improve the accuracy of the solution in critical regions of the domain, including the wellbore, channels or faults, and regions where important variables change dynamically with time, such as the saturation or molar concentration fronts. Usually, the ADM method and its variants have in common that a uniform level is used in each coarse volume, implying that all volumes belonging to a coarse volume at any level must be at the coarse or fine scale. To circumvent this limitation, recently, we have developed the Nun-Uniform Algebraic Dynamic Multiscale solver (NU-ADM) [29], that can handle



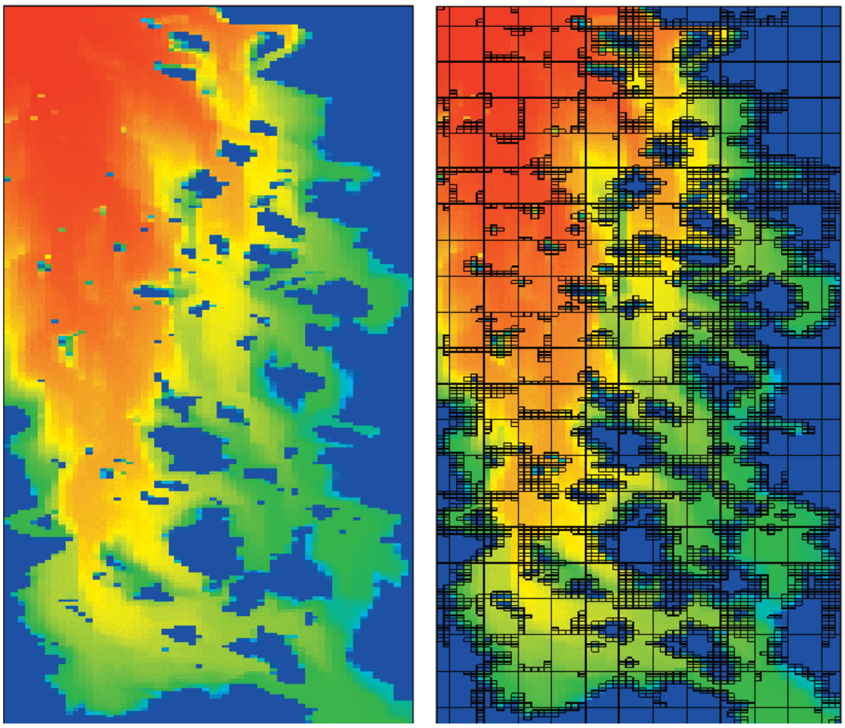
(a) Classical ADM-AMS
$\|e_p\|_2$ =18.7% $\|e_p\|_\infty$ =340%

(b) fine-scale

(c) ADM with A-AMS
$\|e_p\|_2$ =5.6% $\|e_p\|_\infty$ =8%

Figure 5:
Pressure field for the layer 85 of the 10th CSP-SPE, obtained by employing: (a) the standard ADM using the basis functions from AMS; (b) fine-scale (reference) solution; (c) A-AMS with ηlim = 1, over the corresponding dual agglomerated mesh [29].

non-uniform levels at each coarse-scale control volume. Furthermore, a new extension of the AMS (Algebraic Multiscale Solver) [37] that mitigates the unphysical oscillations that occur when the decoupling of basis functions takes place in certain regions of the simulation. In these cases, by examining the coarse-scale matrix, our method detects and performs a local recalculation of the prolongation operator using agglomerated dual coarse volumes chosen adaptively (A-AMS, [29]) to mitigate the spurious oscillations. *Figure 5* presents the improvement of the pressure solution by using A-AMS against the standard AMS, considering the 85th layer of the 10th SPE Comparative Solution Project [29].



(a) (b)

Figure 6:
Two-phase flow simulation for the layer 85 of the 10th CSP-SPE: and saturation fields obtained employing:
(a) fine-scale (reference) solution; (b) Multiscale NU-ADM [29].

Even though MsFV methods have thrived by using structured meshes and linear TPFA discretizations, until recently, very few strategies have been designed to make use of unstructured meshes. In this context, our research group has investigated and developed methods to extend the MsFV (Multiscale Finite Volume) family to allow simulations on general unstructured grids at all scales of the simulation. The Multiscale Control-Volume (MsCV) framework was the first scheme to allow consistent simulation with true unstructured grids. This was achieved by replacing the classical linear Two-Point Flux Approximation (TPFA), which is only consistent on k-orthogonal grids, by the MPFA-D on the Multiscale Restriction Smoothed Basis (MsRSB) [23] procedure. For the set of attempted problems in Souza et al., 2020 [33], the MsCV was capable to reproduce the fine scale solutions using truly unstructured grids in both scales maintaining the most important aspects of physics and with acceptable losses of accuracy.

Another breakthrough was the development of the Algebraic Multiscale Solver for Unstructured grids (AMS-U) [34] as a natural extension of the AMS [37] method. The core aspects of the AMS-U include a new strategy to compute the multiscale geometric entities, i.e., primal and dual coarse grids, the modifications to the prolongation operator to avoid the leakage of the basis function and the use of the MPFA-D method for the fine-scale flux approximation. In *Figure 7* we show water saturation contours at t=0.545 PVI for a problem involving a highly heterogenous and reservoir with two injection wells and one producer.

Modelling Fluid Flow in Naturally Fractured Reservoirs

Naturally fractured reservoirs have received increasing attention from the oil industry as recent estimates indicate that most of the remaining exploitable oil and gas fields are of this type [3]. Fault development, folding, diagenetic processes and sediment subsidence can cause natural rock fractures over geological time, ranging in size from a few micrometres to several kilometres. Modelling multiphase and multicomponent fluid flow in these media is challenging because, in addition to the presence of fractures, there is the natural complexity of the depositional environments and the difficulty of creating appropriate meshes for such cases. In this context, it is fundamental to develop robust and accurate numerical methods capable of dealing with all these challenges and to find suitable models that take into account the influence of fractures in different scales. Classical approaches to handle fractured reservoirs include the use dual porosity and dual permeability models or the use of simple transmissibility multipliers. These approaches are limited, especially when it comes to the simulation of multiphase and multicomponent flows [3]. A more robust and accurate approach involves the use of Discrete Fracture Models (DFM).

In DFM, fractures are explicitly represented at the computational mesh and additional degrees of freedom are associated to these entities [28]. Among the different DFM, we can mention the equidimensional, the lower dimensional (LDFM) and the hybrid grid (HyG) models [6; 28]. In the equidimensional approach, fractures are represented in the geometric mesh with its real aperture by using the mesh elements to represent fractures and the rock matrix. In the LDFMs, flow equations for fractures are discretized separately from the matrix, in a (n−1) dimensional subdomain. On the other hand, in the HyG approach fractures are expanded to n-dimensional objects in the

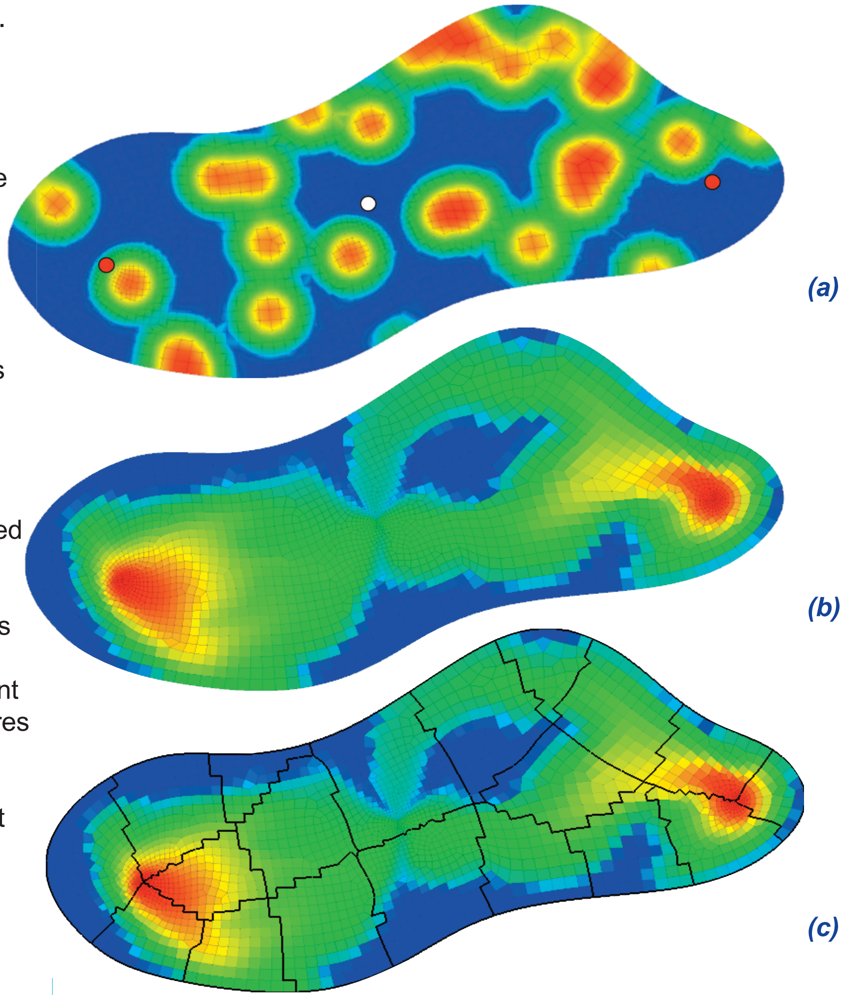
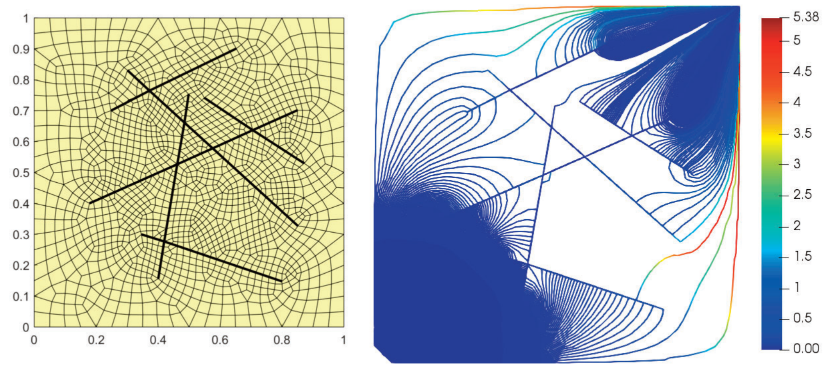


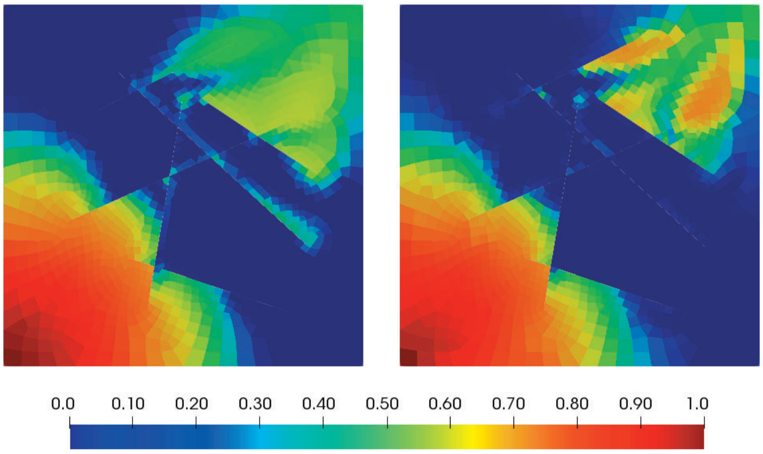
Figure 7.
Two-phase flow of oil and water in a reservoir with a random permeability field: (a) Representation of the log of the permeability field (injection wells in red dots and production well in white dot); (b) Fine scale saturation field; (c) AMS-U multiscale saturation field. Both at t = 0.545 PVI [34].

computational domain, and the equations for fractures and the rock matrix can be discretized together, taking advantage from full pressure support MPFA methods to solve the pressure equation. Therefore, the HyG seems to present a good compromise between accuracy and computational costs, due its capability to properly represent complex geometries and anisotropy within fractures, without the computational overhead associated to the explicit discretization of fractures of the equidimensional approach.

Recently, we have developed the HyG method in the context of the MPFA-D method to solve the pressure equation and the classical FOU (First Order Upwind) method using a Sequential implicit method (SEQ) [6] and the streamline method [36] to solve the saturation equation with an MIMPES (Modified Implicit Pressure Explicit Saturation) methodology. Our strategy has proven to accurately handle oil-water fluid displacements with



(a) Computational configuration *b) Streamlines (PVI – 0.5)*



(c) FOU-HyG PVI - 0.5 *(d) SLS-HyG PVI - 0.5*

Figure 8:
The ¼ of five-spot two-phase flow configuration with multiples connected fractures: (a) Unstructured quadrilateral mesh; (b) Streamlines and time-of-flight field results; (c) Saturation field using SIM with FOU-HyG scheme; (d) Saturation field using MIMPES with SLS-HyG PVI scheme [36].

heterogeneous and anisotropic full permeability tensors for matrix and fractures in naturally fractured reservoirs. In *Figure 8* we consider a ¼ of five-spot configuration in a reservoir with multiple non-aligned and arbitrarily distributed connected fractures. For this and other similar cases, the SLS-HyG method is one order of magnitude faster than the SEQ scheme.

Concluding Remarks

To conclude, we would like to list several other topics of strong interest for those who are planning to get involved with the numerical modelling of fluid flow in heterogeneous and anisotropic porous media, such as: Multiscale-Multiphysics, Sokes-Brinkman (Karst Reservoirs), Geomechanics, Coupling of thermal-hydro-mechanical, Complex setups, EOR (Enhanced Oil Recovery), IOR (Improved Oil Recovery), CO_2 sequestration, Non-conventional gas: tight gas, shale gas, CBM (Coal Bed Methane), Incorporation of all ingredients of HPC, Workflows and Computing, Hybrid models (phenomenological + data driven).

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Deep Reinforcement Learning for Optimal Flow Control

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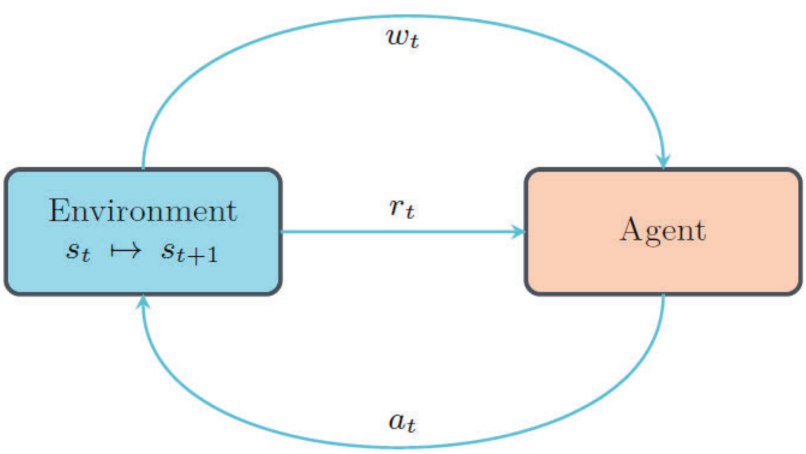
1 Introduction

During the past decade, machine learning methods, and more specifically deep neural network (DNN), have achieved great successes in a wide variety of domains. State-of-the-art neural network architectures have reached astonishing performance levels in image classification tasks [1, 2], speech recognition [3] or generative tasks [4]. With a generalized access to GPU computational resources through cheaper hardware or cloud computing, such advances have been paving the way for a general evolution of the reference methods in these domains, both at the academic and industrial levels.

The quick rise of neural networks has gone along with important progress in the domain of decisionmaking techniques, by the coupling of DNNs with reinforcement learning algorithms (called deep reinforcement learning, or DRL). Several major obstacles that had been hindering classical reinforcement learning have been lifted using the feature extraction capabilities of DNNs, and their ability to handle high-dimensional state spaces. Unprecedented efficiency has been achieved in many domains such as robotics [5], language processing [6], or games [7, 8], but DRL has also proven useful in many industrial applications, such as autonomous cars [9, 10], or data center cooling [11].

The efforts for applying DRL to fluid mechanics are ongoing but still at an early stage, with only a handful of pioneering studies providing insight into the performance improvements to be delivered in the field [12]. Nonetheless, from a few liminal contributions in 2016 [13] and early 2018 [14], the domain has undergone an increasing inflow of contributions, that pinnacled in 2020, with no less than 16 preprints and articles, most of them focusing on academic drag reduction problems. This enthusiasm can be explained by two main factors: first, the sustained commitment from the machine learning community, that has allowed concurrently expanding the scope from computationally inexpensive, low-dimensional reductions of the underlying fluid dynamics to complex Navier–Stokes systems, all the way to experimental set-ups. Second, the increasing number of open-source initiatives [15, 16, 17], that has led to an accelerated diffusion of the methods in the community.

Figure 1:
RL agent and its interactions with the environment



2 Deep reinforcement learning

Reinforcement learning (RL) is a class of methods designed for decision-making problems, in which an agent learns to interact with an environment by
(i) observing it,
(ii) taking actions based on these *figure 1*.
In practice, the reward embodies the objective of the control law, and must be designed on a case-by-case basis for a high value (resp. a low value) to reflect a good choice (resp. a bad choice) of action given the last provided observation. In any given state, the agent seeks the adequate action maximizing its discounted cumulative reward over an episode, defined as:

$$R(\tau) = \sum_{t=0}^{T} \gamma^t r_t \,, \qquad 1)$$

where r_t is the reward received for taking action at given state s_t, T is the horizon of the trajectory (i.e. the terminal time station), and $\gamma \in [0, 1]$ is a discount factor that weights the relative importance of present and future rewards. Such a problem can be formulated as a Markov Decision Process, for which a variety of methods have been developed, that involve estimating either a *value function* (value-based methods), a *policy*, i.e. a probability distribution over actions given states (policy-based methods), or a mixture of both (actor-critic methods)[2].

In a deep reinforcement learning context, the agent is a deep neural network patterned after the neural circuits formed by neurons in human brains. The most general form of neural network architecture is the fully connected DNN, in which the processing units (the artificial neurons) are stacked in layers and information propagates forward from the input layer to the output layer via "hidden" layers. Each neuron performs a weighted sum of its inputs to assign significance with regard to the task the algorithm is trying to learn, adds a bias to figure out the part of the output independent of the input, and feeds an activation function that determines whether and to what extent the computed value should affect the outcome. The neural network learns to represent the relation between input (action) and output (reward) data by repeatedly adjusting the weights and biases by back-propagation, from the output layer back through the hidden layers to the input layer (a process known as training). This is usually done using stochastic gradient method to minimize the value of a well-chosen loss function (representing the quality of the network prediction), most always based on an expected cumulated reward computed using state-action-rewards samples obtained from interacting with the environment.

3 Deep reinforcement learning and flow systems

Regarding the DRL-based control of computational fluid dynamics (CFD) systems, most efforts in the community have so far touted the high potential of the approach on textbook problems, prominently in the context of low Reynolds number drag reduction. Nonetheless, considerable efforts are needed to (i) consolidate the acquired knowledge, (ii) further shape the capabilities of the method, (iii) bridge the gap between DRL and advanced numerical methods for multiscale, multiphysics CFD systems, Two key ingredients are mandatory for this purpose: an efficient DRL algorithm for learning, and a scalable CFD solver to accurately predict the computationally expensive numerical solutions from which to extract the reward fed to the DRL agent. The choice of the latter can dramatically impact on the training time required to reach a well-trained control agent, as performing a relevant network update requires evaluating a sufficient number of actions drawn from the current policy, which in turn requires computing the same amount of rewards from resource-expensive numerical simulations (this can amount to several tens of CPU-hours per reward evaluation).

The Computing and Fluid Research (CFL) group at the Centre for Material Forming processes (CEMEF) research center has gone into DRL-CFD as part of the MINDS project (Mines Initiative for Numerics and Data Science), developed at MINES ParisTech (Paris School of Mines) with the support of the French National Research Agency. MINDS is interested in the convergence of high performance computing and data science, and thus aims at developing a joint digital research and development platform bringing together advances in both fields. The long-term ambition is to revisit the current design of control strategies for computationally-expensive flow problems representative of industrial applications (high Reynolds numbers, complex geometries, multiple phases and/or non-Newtonian fluids), which requires flexible tools that can be easily integrated in tuning-free, ready-to-use, near-real time optimization procedures. We review below pending problems in various scopes (e.g., optimization of steady and unsteady aerodynamics coefficients, control of industrial thermic processes, shape optimization) tackled in this context, for which several DRL algorithms have been coupled to CimLib- CFD, an in-house, massively parallel, multiphysics C++ finite element library. This has been done in a high-performance computing context, to allow distributing actions to multiple environments running in parallel, each of which executes a self-contained MPI-parallel CFD simulation and feeds data to the DRL algorithm (hence, two levels of parallelism related to the environment and the computing architecture).

[2] We restrict here on model-free methods and voluntarilty omit model-based methods, in which the agent interacts with a model of the environment, not the environment itself.

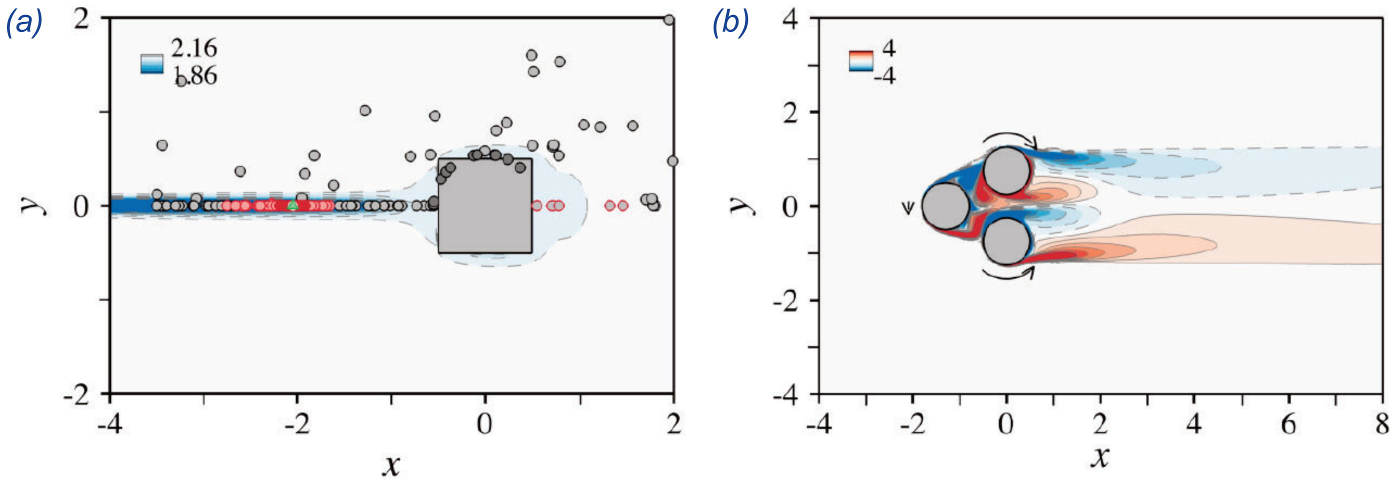
3.1 Drag reduction

Drag reduction is a topic of tremendous societal and economical importance, as reducing the overall drag by just a few percent while maintaining lift can help reduce fossil fuel consumption and CO2 emissions while saving several billion dollars annually in applications such as ocean shipping or airline traffic. In [18], several open-loop drag reduction problems modeled after the unsteady Reynolds averaged Navier–Stokes (uRANS) equations are tackled to showcase the relevance of DRL-CFD for the control of turbulent cylinder flows (with Reynolds numbers ranging from a few thousands up to a few ten thousands, based on the cylinder diameter and the free stream velocity). The DRL algorithm is single-step PPO, a tweaked version of the PPO algorithm (Proximal policy optimization [19], that has quickly gained prominence in the DRL community and is by far the most common algorithm exploited in the context of DRL-based control for fluid mechanics), intended for situations where the optimal policy to be learnt by a neural network does not depend on state. Such an approach proves relevant to map the best positions for placement of a small control cylinder in the attempt to reduce the drag of a square cylinder (*see figure 2(a)*), the achieved reduction by 30% being in good agreement with reference experimental data available from literature. The method also successfully reduces the drag of the fluidic pinball, an equilateral triangle arrangement of rotating cylinders immersed in a turbulent stream. Consistently with reference machine learning results from the literature, drag is reduced by almost 60% using a so-called boat tailing actuation made up of a slowly rotating front cylinder and two downstream cylinders rotating in opposite directions so as to reduce the gap flow in between them; see *figure 2(b)*.

3.2 Thermal control

Thermal control, defined as the ability to finesse the thermal properties of a volume of fluid (and of the solid objects inside) into a certain desired state, is a natural field to extend the scope of the DRL methodology and to increase the complexity of the targeted applications. So far, it has drawn little attention from the community despite its social significance. For instance, heat/cool exchangers are used in a broad range of industrial applications to regulate process temperatures by heat or cool transfer between fluid media, which in turn ensures that machinery, chemicals, water, gas, and other substances remain within safe operating conditions. Green building engineering and aircraft cabin climatization are other

Figure 2:
Drag reduction in the context of turbulent cylinder flows.
(a) Control of the square cylinder flow: the position of a small, circular control cylinder around a main, square cylinder is evolved by DRL in order to minimize the mean drag of the two-cylinder system. The positions investigated by DRL are shown in as the grey circles, with the light red circles showing high reward positions spanned over the course of optimization, and the dark red circles showing those high reward positions spanned over the last 5 episodes. The green triangle is the optimal position determined experimentally at a similar Reynolds number [20].
(b) Control of the fluidic pinball: DRL is used to evolve three cylinders individual angular velocities in order to minimize the mean drag of the three-cylinder system. For this case, the reward comprises two terms, a first term equal to the power of drag and associated to performance, and a second term estimating the power to be supplied to the rotating cylinders and thus associated to cost.



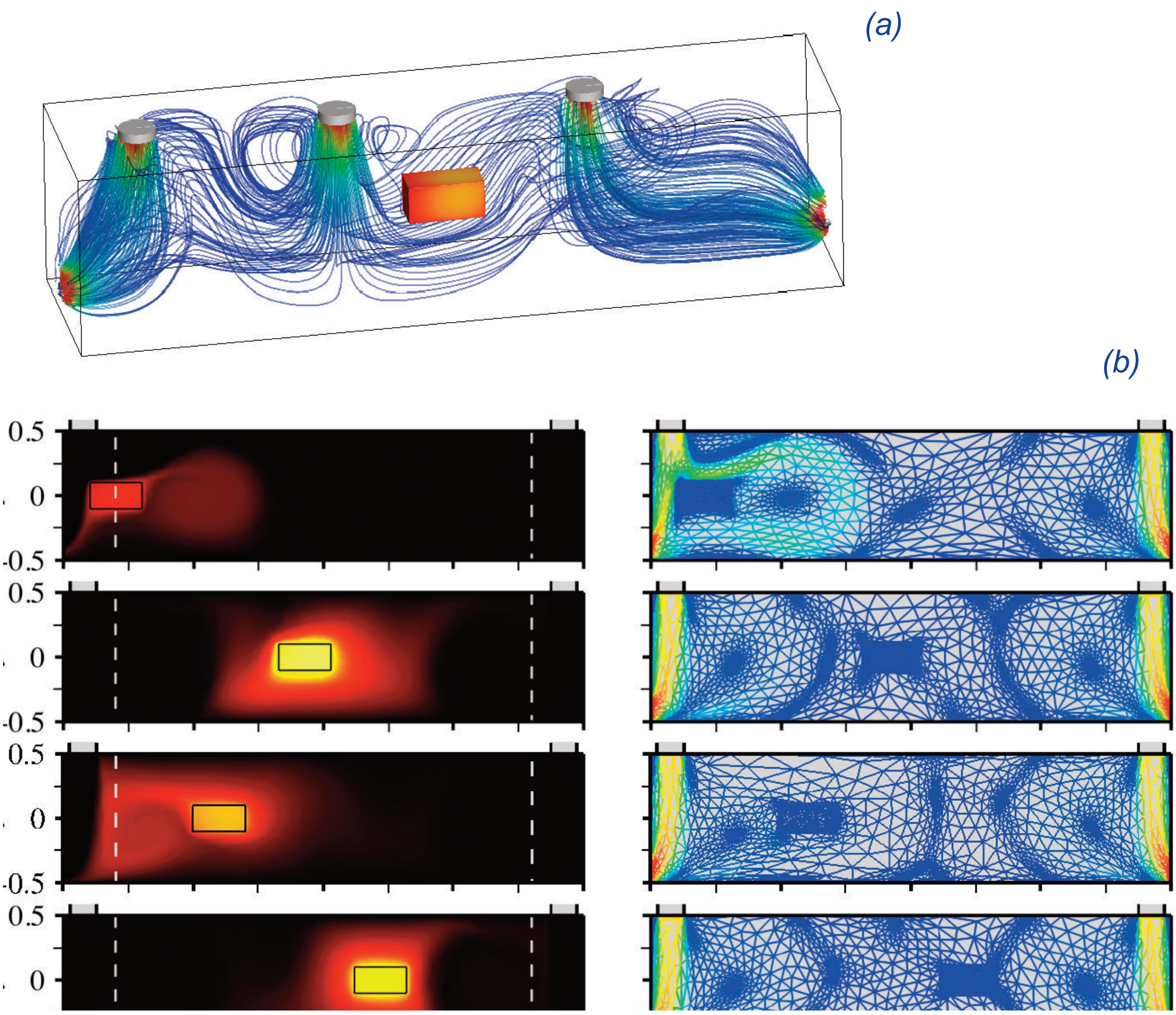


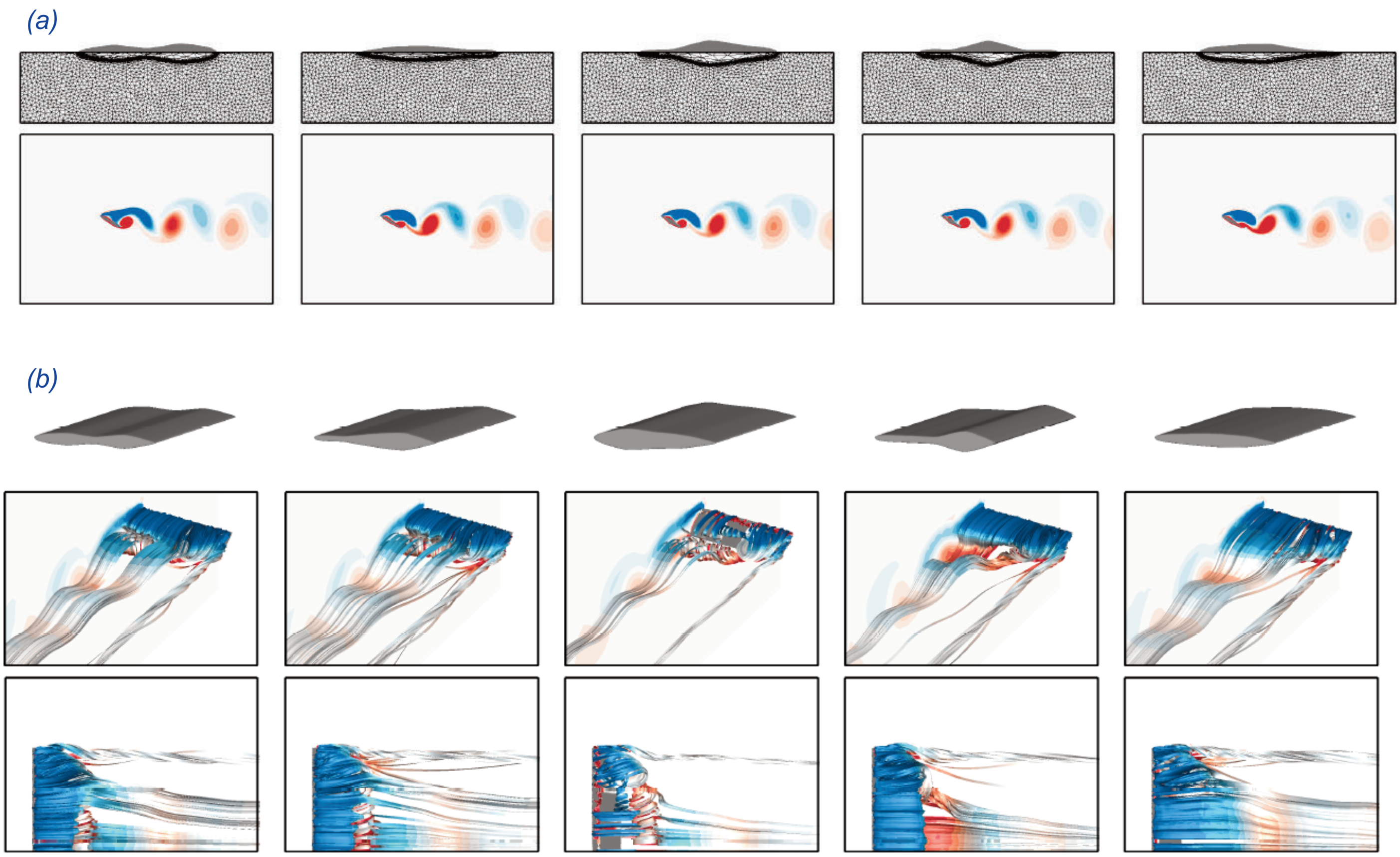
Figure 3:
Forced convection in a rectangular cavity the context of workpiece cooling.
(a) The top cavity side is flush with 3 identical holes whose distribution is optimized by DRL in order to minimize the local temperature gradients of a 3-D workpiece.
(b) The position of a 2-D workpiece relative to two fixed injectors is optimized for the same purpose, with the optimal position shown at the bottom

fields focusing on regulating indoor thermal conditions (temperature, humidity).under substantial variations of the ambient conditions to provide high-quality comfort environments. In many manufacturing processes, thermal conditioning is also intended to improve the final mechanical (e.g., hardness, toughness, resistance), electrical, or optical properties of the product, the general picture being that high temperature gradients are useful to speed up the process but generally harm the quality of the outcome because of heat transfer inhomogeneities caused by the increased convection by the fluid particles. In [21], the scope of single-step PPO is extended to the control of conjugate heat transfer systems governed by the coupled Navier–Stokes and heat equations. The approach is found capable of improving the homogeneity of temperature across the surface of two and threedimensional hot workpieces under impingement cooling. Several control strategies are assessed, for which the position of multiple cold air injectors is optimized relative to a fixed workpiece position, whose increasing design complexity translates into less constrained operation when it comes to optimizing a practically meaningful device. For instance, a so-called fixed domain decomposition strategy in which each injector is forced to sit in a different subdomain yields a heavily constrained optimization problem, relevant for cases where the design is rigid and the practitioner has limited freedom to act. Conversely, a so-called free strategy, in which all injectors are independent and free to move along the top cavity wall, yields a mildly constrained optimization problem, relevant for cases where the design is flexible and the practitioner has great freedom to act. The flexibility of the CFD numerical framework also allows optimizing the workpiece position relative to a fixed, symmetrical actuation injector distribution. The optimal position turns to be offset from the symmetry axis, which had not been anticipated, and stresses the ability of the DRL-CFD framework to effectively explore and discover non-trivial solutions from unforeseen parameter combinations.

3.3 Wing shape optimization

Shape optimization is ubiquitous in engineering applications ranging from magnetostatics, image restoration and segmentation, to nano-optics, just to name a few. Shape optimization in fluid mechanics dates back to the pioneering work of Pironneau on the minimization of energy loss in Stokes and Navier–Stokes flows [6, 7]. Since then, it has become an increasingly important research topic in the attempt to enhance drag reduction capabilities, which is due to the ever growing concerns on aerodynamic energy efficiency. Shape optimization generally consists in figuring out a fixed shape meeting a set of required criteria (e.g. high lift-to-drag ratio, low pressure loss) and therefore requires optimizing state-independent parameters, which is per se the original purpose of single-step DRL. In [22], Policy based optimization (PBO [23]), an in-house algorithm developed by the CFL group under the premise that convergence to the optimal can be made faster if actions are sampled anisotropically from full covariance matrices, is applied to aerodynamic shape optimization problems. Two-dimensional airfoil sections with fixed camber line, chord direction and angle of attack are generated by varying a chord length and a thickness distribution. The uppe and lower sides are discretized into a small number of control points equally spaced in the camber line direction. All shapes are closed and symmetrical with respect to the chord line, as achieved forcing zero thickness at the edges and identical (half)-thicknesses at each forward and rearward facing points. Following the seminal work of [17], consecutive points are connected by a cubic Bézier curve using local position and curvature information. The final step consists of sampling all Bézier curves and in exporting a closed loop, to be either used as an immersed mesh in a 2-D environment, or extruded in the off-body direction to serve as an immersed mesh in a 3-D environment. At zero incidence, the proposed framework successfully

Figure 4:
Shape optimization in the context of optimal wing design. DRL is used to maximizethe lift-to-drag ratio under the constraint of a fixed section area using (a) 2-D and (b) 3-D environments



reduces the drag of the equivalent cylinder (i.e., the cylinder of same cross-sectional area) by 48% at a Reynolds numbers in the range of a few hundreds. At an incidence of 30, it increases the lift to drag ratio of the equivalent ellipse by 13% in 2-D and 5% in 3-D at a chord Reynolds numbers in the range of a few thousands (figure 4). Although the low number of degrees of freedom inevitably constrains the range of attainable shapes, the optimal is systematically found to perform just as well as a conventional airfoil, despite DRL starting from the ground up and having no priori knowledge of aerodynamic concepts. ●

" Although the low number of degrees of freedom inevitably constrains the range of attainable shapes, the optimal is systematically found to perform just as well as a conventional airfoil, despite DRL starting from the ground up and having no priori knowledge of aerodynamic concepts."

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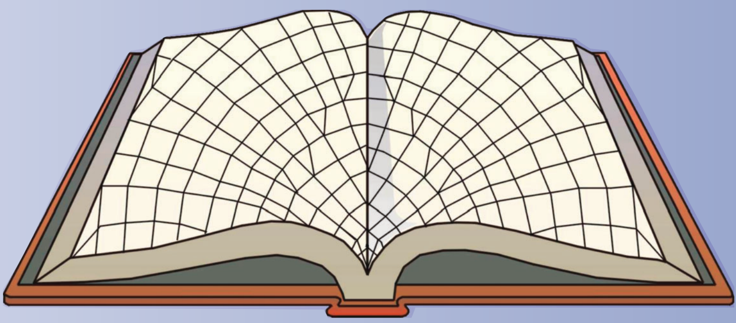
A Primer on Mathematical Modelling



Alfio Quarteroni & Paola Gervasio
Springer, Cham, Switzerland, 2020

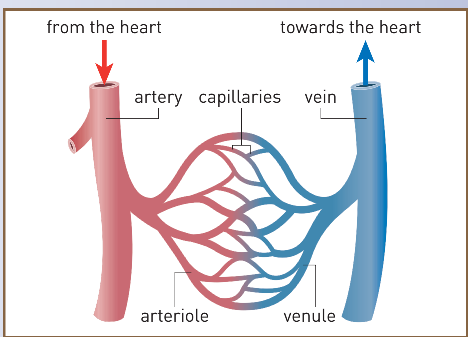
BOOK REVIEW

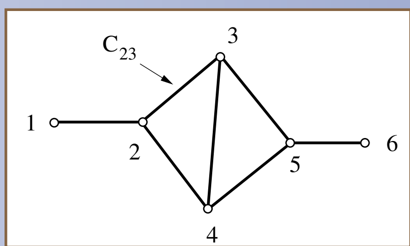
ISBN: *978-3-030-44540-9, 238 pages, soft cover, €20 (List Price).*
Contents: *Preface; About the Book; Main Symbols; 1: A Warm-Up to Models; 2: Getting Started; 3: Reckoning with the Computer; 4: A virtual Surfer for the Web; 5: A network of Capillaries; 6: Predators and Preys in the Maths Ocean; 7: Take-Home Message; 8: Solutions to Exercises; Index.*

So far, this Book Review section has always reviewed books written for readers who are members of the Computational Mechanics (CM) community. This book (translated from Italian by the applied mathematician S.G. Chiossi), is an exception, as it is apparently intended for another type of audience, such as talented high-school students, students of the non-exact sciences (such as humanities and social sciences) who venture into the territory of modeling, and in general – curious people who are interested to know what modeling is about, and perhaps wish to start practicing it in their area of interest. As a consequence, the book requires no background in calculus or linear algebra. A reader who has not heard of a derivative or a vector can still read this book and understand how modeling is done, through careful explanations and several important scientific examples. This is an impressive educational achievement.

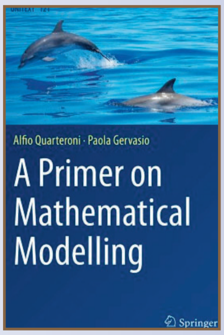
The book is extremely well written and is spectacular in its beauty. It is full with colorful pictures and figures, with many clear graphs, algorithms, codes (written in Octave) and tables, which makes reading the book a real joy. The topics it covers include numerical integration (only the most basic integration rule is discussed), Gauss elimination for the solution of the system Ax=b (chap. 2), round-off errors (chap. 3), fixed-point iteration and the Google algorithm for ordering sites (chap. 4), modeling the blood system (chap. 5; see figure below); finite difference calculation of the derivative, and the Euler method for solving an ODE and a system of ODEs (chap.

This is a superb book for readers doing their initial steps in the wonderful world of modeling. I recommended it to my 17-year-old nephew, who is now reading it with great enthusiasm. ●





Modeling the blood system.
Left: a capillary bed (Fig. 5.2 of the book).
Right: graph representation
(part of Fig. 5.12 of the book)



by
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KSCM 2021 Winter Workshop

KSCM 2021 Winter Workshop was held in the Seoul Lotte World Tower, Seoul, Korea, on 17 December 2021. The workshop organized by the Korean Society for Computational Mechanics aims to bring together Korean researchers in the field of computational mechanics and to encourage research exchange and networking. Thirty seven professors gathered and listened to research on autonomous driving and computational mechanics of cars, UAMs and marine vehicles.

Three speakers – Kichun Jo (Konkuk University), Seungkeun Kim (Chungnam National University) and Jinwhan Kim (KAIST) – gave lectures on the recent technology in the autonomous drive of vehicles related with the computational mechanics.

Further information will be found at: http://www.kscm-society.org/.

Figure 1:
A speaker gave a presentation

Figure 2:
The former KSCM president, Prof. Chae gave a congratulatory speech

Figure 3:
The commemorative photo of participants

MINISYMPOSIUM GIMC (Italian Group of Computational Mechanics) at the AIMETA Congress, *Palermo, September 4-9, 2022*

The AIMETA Computational Mechanics Group (GIMC) is organizing the Minisymposium "Novel Approaches in Computational Mechanics" at the AIMETA Congress, in Palermo on September 4-9, 2022.

A special session will be devoted to the presentation of the PhD theses in Computational Mechanics winner of the GIMC award 2021.

A special session will be organized for young researchers in which the best presentation will be awarded.

All the details can be found at the web site:
www.pa22.aimeta.it

GIMC Best PhD Thesis Award

The GIMC Best PhD Thesis Awards committee, composed by Umberto Perego (Politecnico di Milano), Maria Laura de Bellis (Università degli Studi "Gabriele d'Annunzio" Chieti-Pescara), Antonia Larese (Università di Padova) and Michele Marino (Università di Roma Tor Vergata), selected the following theses, defended in 2021, as the best Theses in Computational Solid and Fluid Mechanics:

- **Dr. Donatella Passiatore,** Politecnico di Bari, *"Direct Numerical Simulations of hypersonic turbulent boundary layers with thermochemical non-equilibrium effects"*. This thesis was also selected as candidate to the ECCOMAS PhD Award

- **Dr. Alessia Patton**, Università di Pavia, *"Advanced isogeometric methods with a focus on composite laminated structures"*.

GIMC SIMAI YOUNG 2022

GIMC (Gruppo Italiano di Meccanica Computazionale) and **SIMAI (Società Italiana di Matematica Applicata e Industriale)** are glad to announce that their first joint workshop for young scientists (≤ 35-year-old) will take place in Pavia on September 29-30, 2022.

The meeting aims at providing participants with a platform to exchange their most recent results, to keep up-to-date on new trends and to foster their interactions.

The program includes two plenary lectures delivered by leading scientists, a session dedicated to the recipients of the GIMC-SIMAI young awards, parallel thematic sessions organized by the participants, as well as contributed sessions. Contributions are welcome from all areas of applied mathematics and computational mechanics.

The initiative is also supported by the ECCOMAS Young Investigators Committee. Follow the committee on ***Facebook, Instagram, Twitter, LinkedIn***.

All the details can be found at the web site:
www.gimcsimaiyoung2022.unipv.it

GIMC Gruppo Italiano di Meccanica Computazionale

SIMAI SOCIETÀ ITALIANA DI MATEMATICA APPLICATA E INDUSTRIALE

EYIC

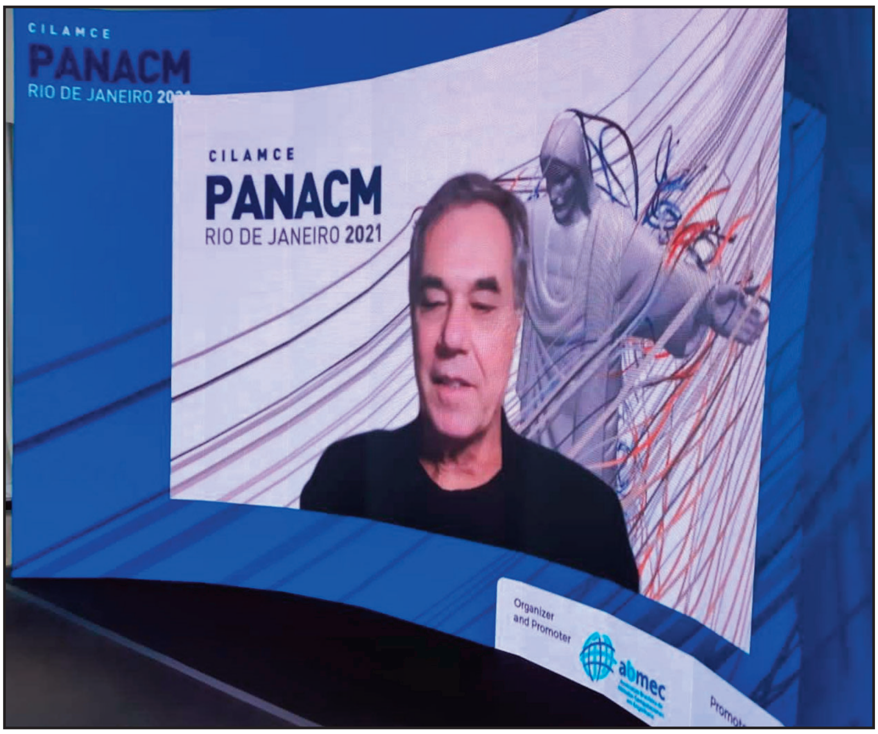
abmec

Associação Brasileira de Métodos Computacionais em Engenharia

ABMEC, the Brazilian Association for Computational Methods in Engineering, is celebrating this year its 25th anniversary. Since its foundation, on September 15, 1997, ABMEC has continuously increased its number of members and promoted the importance and the novelty issues of the Computational Mechanics area in Brazil.

In the last two years, similarly to the rest of the world, the effect of the COVID-19 crisis on the Brazilian scientific community has been profound. Nevertheless, ABMEC could promote two very successful congresses, both in the virtual format. In 2020, the XLI CILAMCE (XLI Ibero-Latin American Congress on Computational Methods in Engineering) was bravely organized under the chair of Prof. Aref K. L. Kazan from the Federal University of the Latin-American Integration – UNILA). The congress took place within a virtual platform specially designed for CILAMCE-2020. Despite the enormous challenge in organizing, for the first time, a conference in the virtual format, CILAMCE-2020 was a tremendous success, receiving 640 participants from all parts of Brazil, Latin America, and a few other colleagues from farther abroad.

III-Pan-American Congress on Computational Mechanics



In 2021, the third PANACM (III-Pan-American Congress on Computational Mechanics) was organized by ABMEC, for the first time jointly with CILAMCE in its XLII edition.

The format was still virtual, but a studio based in Rio de Janeiro was used to broadcast the live participation of the plenary speakers, coordinated by the chairman Prof. Alvaro Coutinho from the Federal University of Rio de Janeiro.

The event's success was demonstrated in the 555 pre-recorded talks, 48 mini-symposia, and 662 participants from Brazil and several parts of the world.

Now that the pandemic crisis seems to be under control, we are very excited about the optimistic prospects of a year of in-person reunions. The milestone of the Brazilian Computational Mechanics community is the fully in-person XLIII CILAMCE, which will be held from November 21 to 25 in Foz do Iguaçu, Paraná, Brazil. The organization is under the chair of Profs. André Jacomel Torii and Marco André Argenta. CILAMCE is a multidisciplinary event: scientists and engineers from all fields are encouraged to attend the conference. The technical program typically includes worldly prominent plenary speakers and several mini-symposia parallel sessions with contributed papers. In this edition, CILAMCE will also include novel social activities of interaction and scientific dissemination on the last day of the event.

The web page of the event is **https://www.cilamce.com.br/** and the deadline for full paper submission is July 11, 2022. Upon request abstracts may still be submitted.

You are very welcome to join us at the world´s wonder of Iguaçu Falls for the upcoming XLIII CILAMCE!

Promoter:

Organizer:

MECOM 2021
XXXVII Argentine Congress on Computational Mechanics
Resistencia, Chaco, Argentina
1 – 5 November 2021

The XXXVII Argentine Congress on Computational Mechanics (MECOM 2021) took place from November 1st through November 5th, 2021, in the city of Resistencia, Chaco, Argentina. This new edition of the annual AMCA Congresses was organized in fully virtual mode by the Computational Mechanics Laboratory (LAMEC), dependent on the Faculty of Engineering of the National University of the Northeast (UNNE) and the National Scientific and Technical Research Council (CONICET), together with the Argentine Association for Computational Mechanics (AMCA).

The Organizing Committee included Prof. Javier L. Mroginski (Chairman), Prof. José Basterra, Prof. Pablo Beneyto, and Prof. Juan M. Podestá (General Coordinator). The Scientific Commitee was chaired by Prof. Hugo G. Castro with Dr. Rodrigo R. Paz and Prof. Gustavo A. Aucar as Co-Chairmen and Prof. Mario E. De Bortoli as General Coordinator.

The Congress hosted ten Invited Lecturers, Prof. Deborah Sulsky (University of New Mexico, USA), Prof. Rainald Löhner (George Mason University, USA),

Figure 1:
MECOM 2021 staff at the Faculty of Engineering of the National University of the Northeast (UNNE)

Figure 2:
Prof. Guillermo Etse and Prof. Paul Steinmann

Figure 3:
Prof. Rainald Lohner and Prof. Sergio Oller

Figure 4:
Participants of the Congress during Q&A of a session

Prof. Sergio Oller (National University of Salta, Argentina), Prof. Norman Fleck (Cambridge University Engineering Department, UK), Prof. Armando Awruch, (CNPq Researcher, Brasil), Prof. Martín Idiart (National University of La Plata, Argentina), Prof. Gustavo Buscaglia (University of São Paulo, Brazil), Prof. Pedro Arduino (University of Washington, USA), Prof. Matteo Parsani (King Abdullah University of Science and Technology, Saudi Arabia) and Prof. Paul Steinmann (University of Erlangen-Nürnberg, Germany). Also, three Keynote Lectures were delivered by Prof. Laura Morales (University of Buenos Aires, Argentina), Prof. Alex Ferrer (Polytechnic University of Catalonia, Spain), and Prof. Mauro Innocente (Coventry University, UK). Most of these lectures are available on the Congress' YouTube channel: **https://bit.ly/MeCOM2021**.

Full-length papers were submitted to a peer review process prior to publication. Accepted papers have been published in the proceedings series "Mecánica Computacional", which are openly available at the following website: **http://www.amcaonline.org.ar/mcamca**. The Conference consisted of 21 Technical Sessions with more than 230 papers presented.

A special session was devoted to undergraduate students, with awards for best posters, that were granted to:

1. Rodrigo R. Velazquez, from the National University of Córdoba, Argentina.
2. Lucas J. Donnet and Maximiliano O. Frutos from the National Technological University (UTN) at Santa Fe, Argentina.
3. Arthur M. Carvalho, from the Federal University of Unipampa, Brazil.

The Congress also included other activities like the X Meeting of OpenFOAM users and the special session to honor Prof. Armando M. Awruch for his retirement.

MECOM 2021 logo

CALL FOR PAPERS

The Argentine Association for Computational Mechanics (AMCA) announces the XXXVIII Argentine Congress on Computational Mechanics (MECOM 2022), to be held in Bahía Blanca, Argentina, organized by Grupo de Investigación en Multifísica Aplicada (GIMAP), of the Universidad Tecnológica Nacional (UTN), Universidad Nacional del Sur (UNS) and AMCA. The following speakers have already confirmed their participation at the MECOM 2022: Marian Wiercigroch (University of Aberdeen, Scotland), Tim Collonius (Caltech, USA), Marcelo Savi (Universidade Federal do Rio de Janeiro, Brazil), Alper Erturk (Georgia Institute of Technology, USA) and Elbio Palma (Universidad Nacional de Sur, Argentina).

https://amcaonline.org.ar/mecom2022/

USACM Elects New Executive Committee Members

USACM recently held its elections for one new officer and four members-at-large. The terms begin August 1, 2022. The results are as follows:

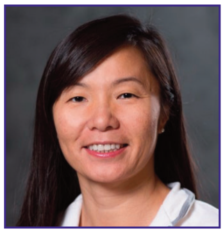
Secretary/Treasurer:
Yongjie Jessica Zhang, Carnegie Mellon University
The Secretary/Treasurer will rotate to the office of President during the next four years.

Members-at-Large:
The members-at-large serve a four-year term on the Executive Committee

John Evans
University of Colorado at Boulder

Hector Gomez
Purdue University

David Littlewood
Sandia National Laboratories



Lucy Zhang
Rensselaer Polytechnic Uni.

Virtual Thematic Conference on the Role of Mathematical and Computational Modeling in Cancer Research

The USACM Technical Thrust Area (TTA) on Biological Systems, with support from the Oden Institute for Computational and Engineering Sciences at the University of Texas, hosted a virtual Thematic Conference on the Role of Mathematical and Computational Modeling in Cancer Research, January 10-11, 2022. Organized by Drs. Prashant K. Jha, Ernesto A.B.F. Lima, and Chengyue Wu, all from the Oden Institute, the conference brought leading computational oncology experts together in one platform to share their work and vision for integrating quantitative biological data with mechanistic mathematical models. Invited presentations were made by: Professors Luciana R C Barros, Heiko Enderling, David Fuentes, Hector Gomez, John D. Hazle, Mohit Kumar Jolly, John Lowengrub, J. Tinsley Oden, Savannah Partridge, Katarzyna Rejniak, Russell Rockne, and Thomas Yankeelov. Several short talks were also presented from abstract submissions. Contact the USACM office at **admin@usacm.org** for information about how to access videos of these talks.

TTA Virtual Seminars

Several TTAs (Technical Thrust Area) of the USACM have been holding monthly virtual seminars which have featured guest speakers and discussions on various topics of importance to their field. Videos of the talks may be found at usacm.org/ttas under the TTA of interest. The following talks have taken place since September 2021:

TTA on Computational Fluid Dynamics and Fluid Structure Interaction

Yuri Bazilevs, (Brown University), *Advanced and Practical Fluid-Structure Interaction*

Tayfun Tezduyar (Rice University), *Space-Time Computational Analysis: From Inception to New Generations*

Marilyn Smith (Georgia Tech), *High-Fidelity Aeroelasticity Simulations for Rotating Systems*

Michael Sprague (National Renewable Energy Laboratory), *Predictive Simulations of Wind Turbines on Next-Generation Supercomputers*

Lucy Zhang (Rensselaer Polytechnic Institute), *Numerical Coupling Workflow of Multiphysics Interactions Using Immersed Methods*

Arif Masud (University of Illinois at Urbana-Champaign), *Variational Multiscale Discontinuous-Galerkin (VMDG) Method for Couple Fluid-Solid Systems: Theory and Applications*

Guglielmo Scovazzi (Duke University), *The Shifted Boundary Method for CFD*

TTA on Large Scale Structural Systems and Optimal Design

Evgueni T. Filipov (University of Michigan), *Simulating Shape Morphing Origami: Kinematics, Mechanics and Multi-Physics*

Matthew J. Zahr (University of Notre Dame), *High-Order and Reduced-Order Methods for Improved Engineering Analysis and Design*

Jifu Tan (Northern Illinois University), *Multiphysics Modeling of Biological Flows with Cell Suspensions*

Narasimha Boddeti (Washington State University), *Optimal Design and Manufacture of Architected Fiber Reinforced Composites*

Som L. Dhulipala (Idaho National Laboratory), *Active Learning for Accelerating Expensive Computational Tasks in an Open-Source High-Performance Computing Platform*

Masoud Behzadinasab (Brown University), *Peridynamics for Simulation of Fracture Mechanics Problems.*

TTA on Uncertainty Quantification and Probabilistic Modeling
(see TTA website for more information on speakers before September 2021)

Yeongjong Shin, Brown University (Discussant: Dongbin Xiu), *Mathematical Approaches for Robustness and Reliability in Scientific Machine Learning*

Catherine Gorlé Stanford University (Discussant: Gianluca Iaccarino), *Uncertainty Quantification and Data Assimilation for Predictive Computational Wind Engineering*

Audrey Olivier, USC (Discussant: Lori Graham Brady), *Bayesian Learning of Neural Networks for Small or Imbalanced Data Sets*

Johann Guilleminot, Duke University (Discussant: Roger Ghanem), *Stochastic Modeling for Physics-Consistent Uncertainty Quantification on Constrained Spaces, with Various Applications in Computational Mechanics*

Danial Faghihi, University at Buffalo (Discussant: J. Tinsley Oden), *Toward Selecting Optimal Predictive Computational Models*

Ioannis Kougioumtzoglou, Columbia University (Discussant: George Deodatis), *Path Integrals in Stochastic Engineering Dynamics*

Jian-xun Wang, University of Notre Dame (Discussant: Michael Brenner), *Leveraging Physics-Induced Bias in Scientific Machine Learning for Computational Mechanics – Physics-Informed, Structure-Preserved Learning for Problems with Complex Geometries* ●

USACM Upcoming Events
further details at usacm.org

- **Meshfree and Novel Finite Element Methods with Applications**
  September 25-27, 2022, Berkeley, CA **(mfem2020.usacm.org)**
- **IGA 2022,** November 6-9, 2022, **Banff, Canada (iga2022.usacm.org)**
- **17th U.S. National Congress on Computational Mechanics**
  July 23-27, 2023, Albuquerque, New Mexico **(17.usnccm.org)** ●

SFB/TRR 339 – Digital Twin of the Road System

Physical-Informational Representation of the Future Road System

The mobility of people and goods is a central basis of our modern society with increasingly global and diverse networked processes. In its present form, mobility, especially with regard to road traffic, is currently confronted with global challenges (durability, safety, efficiency, ecology, costs, automation etc.) that urgently require fundamental solutions.

In the SFB/TRR 339 (TU Dresden, RWTH Aachen, speaker: Prof. Michael Kaliske, Insitute for Structural Analysis, TU Dresden), a spatially and temporally multi-dimensional, digital/virtual image (reality model in space and time) of vehicle, tires and road surface (concrete and asphalt) taking into account the road pavements (integrated multi-functionality) will be developed and researched. The reality model combines all available and relevant information about the "Road of the Future" from physical investigations and modeling as well as from informational and traffic data (sensor data, data models etc.). It enables and requires the interaction between the physical-structural and the informational-traffic design level. This interactive reality model in space and time is called the digital twin of the road system and is used in perspective to analyze, control and forecast the physical original (real road system consisting of vehicle, tires, lane, nearby street space) by means of common interfaces. The advancement of the road to a high-tech platform will be developed using the new, interdisciplinary research approach (civil engineering, computer science, society).

The research approach is based on a three-stage development strategy:
In Phase I, the required submodels are designed and developed.
In Phase II, the partial models are combined using common, standardized interfaces and integrated into a holistic model of the road system (digital shadow), which in Phase III will allow the analysis and control of the road system with its own control components (digital twin).

The aim is to achieve the vehicle's present high level of development in a similar way for the road system, so that a new quality of integration of vehicles and infrastructure can be achieved. The overriding aspects of law and sustainability shall be explicitly included into the conception and development of the digital twin of the road system from the beginning on. The digital twin of the road system will lead to an intelligent, gentle and sustainable use of the road infrastructure. Other expected results are groundbreaking condition forecasts, interfaces to local traffic control, the optimal synthesis of building materials and structures, interfaces to automated driving and the reduction of emissions, e.g. by minimizing traffic jams or durable road infrastructure components (use of resources).

Further information:
https://tu-dresden.de/bu/bauingenieurwesen/sdt/forschung/sfb-339digitaler-zwilling-strasse

SFB TRR 339

DFG SPP 2311 - Robustly coupling continuum-biomechanical in silico models to obtain active biological system models for later use in clinical applications

Co-design of modeling, numerics and usability

The enormous potential of in silico (computer-aided) models is still little utilized in medicine. As in other high-tech fields, this potential could be exploited more intensively to accelerate the development of modern diagnostic and individualized treatment methods. Most existing in silico models are limited to single scales (e.g. cell, tissue) or to generic multi-scale models of single organs (e.g. muscle, liver). However, to understand symptoms and disease, multiple scales of size and time must be considered in the context of the entire system. The complex cross-scale relationships are often very difficult to identify without a systematic approach and computational models. Therefore, a central task of numerical biomechanics and biomedical research is to develop robust coupling methods and strategies. These must integrate the scales of biological systems from the molecule to the complete organ system or organism.

In order to promote this emerging research field, the German Research Foundation (DFG) has approved a new Priority Programme (SPP2311) on the "Robust Coupling of Continuum-biomechanical In Silico Models to Establish Active Biological System Models for Later Use in Clinical Applications – Co-design of Modelling, Numerics and Usability". The programme consists of 11 research projects, each of which being a collaborative effort of interdisciplinary, Germany-wide research groups from medicine, mathematics, computer science and engineering. The programme is coordinated by Prof. Oliver Röhrle, PhD, Director of the Institute for Modelling and Simulation of Biomechanical Systems at the University of Stuttgart.

The overall aim of the SPP is to further existing methodologies to achieve a new generation of robust biomechanical models that ultimately can be used in clinical practice. In that sense, the SPP aims to develop the enabling methodologies to build new complex models for clinical applications, but does not aim to transfer these new models to clinics via clinical studies, yet. Thus, the SPP understands itself as a methodically oriented programme focusing on computational biomechanical models of active systems for medical questions.

The SPP is divided into three closely interrelated areas. The area "Modeling of coupled biomechanical systems" deals with the coupling of biomechanical in silico models for the description of active biological systems on different length, time and/or function scales or with the coupling of continuum biomechanical organ system models. The area "Numerics of coupled biomechanical systems" focuses on mathematical algorithms for robust, numerical solution of coupled models for active biological systems as well as their implementation on workstations and supercomputers. And finally, the area "Usability" deals with data exchange, validation and preparation of numerical continuum biomechanical models for answering clinically relevant questions and for person-specific solutions. ●

Further information: **https://www.spp2311.de/**

JACM 日本計算力学連合

Japan Association for Computational Mechanics

The Japan Association for Computational Mechanics (JACM) is a union of researchers and engineers working in the field of computational mechanics mainly in Japan. The JACM is a loosely coupled umbrella organization covering 29 computational mechanics related societies in Japan through communication with e-mail and web page (https://ja-cm.org/index-e.html). The number of individual members is about 330. JACM members actively participate in the IACM activities.

On December 10th, 2021, the first JACM awardee seminar was held online. The purpose of this seminar series is to have young researchers who received the JACM awards recently give lectures on their latest research activities. Two lectures were given in the seminar. The first one entitled “A Nestable, Multigrid-friendly Grid on a Two-dimensional Sphere with an Exact Quadrature Rule” was presented by

Figure 1: *Group Photo of first seminar held on December 10th 2021*

Figure 3: *Professor Yuto Otoguro*

The Computational Mechanics Symposium

The Computational Mechanics Symposium is an annual event that has been held in December every year for 10 years, since 2011. Young researchers representing computational eight mechanics related professional societies presented. On Monday, December 6, 2021, JACM took a part of the 11th Computational Mechanics Symposium. The symposium is organized by the Science Council of Japan (SCJ) in association with eight computational mechanics related academic societies in Japan. The function of SCJ is defined as “The Science Council of Japan was established in 1949 as a “special organization” under the justification of the Prime Minister, operating independently of the government for the purpose of promoting and enhancing the field of science, and having science reflected in and permeated in administration, industries and people’s lives. It represents Japan’s scientists both domestically and internationally …” (**http://www.scj.go.jp/en/scj/index.html**). Due to the pandemic of the Covid-19, Dr. Daisuke Hotta (Japan Meteorological Agency), who is the JACM Young Investigator Award (YIA) winner of year 2021. The second one was "Hierarchical Domain Decomposition Method, and Its Application to the Parallel Electromagnetic Field Analysis" given by Professor Shin-ichiro Sugimoto (Hachinohe Institute of Technology), received the YIA of year 2019.

Following the successful first seminar, the second seminar was held on March 17th, 2022. Professor Kazuya Shibata (University of Tokyo), the YIA winner of year 2018, gave the lecture entitled "Multi-resolution Particle Methods for Fluid Analysis and Their Applications in Engineering." Then, Professor Shunhua Chen (Sun Yat-sen University), received the YIA of year 2021, presented the lecture of "Fracture Simulations of Laminated Composite Structures Subjected to Various Loading Conditions."

The JACM plans to hold this seminar series twice or three times a year in the future. ●

Figure 2: *Group Photo of second seminar held on March 17th 2022*

the symposium was held in a mixed face-to-face/online hybrid format.

Professors Seiichi Koshizuka (UTokyo) and Kazuo Furuta(UTokyo) served as the general chairs. After the opening remark by Professor Shinobu Yoshimura (UTokyo), eight young researchers representing the participating computational mechanics related societies presented their latest research accomplishments. Majority of them were the recent award recipients of the participating societies. Professor Yuto Otoguro (Tokyo Univ. Science, Photo 3) was the recipient of the 2021 JACM Young Investigator Award. He gave a talk "Space–Time Computational Methods and Isogeometric Discretization for Flow Problems with Complex Geometries and Moving Boundaries and Interfaces". After the talks by the young researchers, Professors Keiko Takahashi (Waseda Univ.) and Yasuyuki Takata (Kyushu Univ.) delivered key-note presentations on issues related with SDGs (Sustainable Growth and Developments) were given by followed by discussions. ●

* *In the precious issue, the name of **Professor Yoshihiro Tomita** (Emeritus Professor of Kobe University, Specially Appointed Professor of Kyoto Institute of Technology) was missing from the list of newly inducted Honorary Members of JACM.*
We would like to apologize for making this editorial error.

SEMNI changes its name

During the last general assembly of SEMNI, held on March 23th, 2022, our society agreed on changing its name. Soon after our 30th anniversary, the executive committee felt that the original name of our society (Sociedad Española de Métodos Numéricos en la Ingeniería—Spanish Society for Numerical Methods in Engineering) no longer reflects many of the activities of our members. A proposal was elevated to the general assembly to change the name of our society. The proposal suggested the name “Sociedad Española de Mecánica e Ingeniería Computacionales” (Spanish Society of Computational Mechanics and Computational Engineering).

This proposal was approved by the general assembly, together with the proposal of maintaining, for historical reasons, the acronym of the society, SEMNI.

All this is already reflected in the new web page, **www.semni.org**. ●

SEMNI Juan C. Simó award 2021

SEMNI has awarded its annual Juan C. Simó prize during its last executive meeting. The awardee will receive his prize during the gala dinner ceremony of the joint Spanish-Portuguese Conference on Numerical Methods, CMN, to be held in Las Palmas de Gran Canaria next September 2022.

SEMNI’s prize to young researchers commemorates the legacy of the late Professor Juan C. Simó in the field of numerical methods. The committee was formed in this occasion by Kerstin Weinberg (Department of Mechanical Engineering, Universität Siegen), Olivier Allix (Laboratoire de Mécanique et Technologie, ENS Paris-Saclay) Jose Paulo Moitinho de Almeida (Department of Civil Engineering, Architecture and Georesources of Instituto Superior Técnico, Universidade de Lisboa) and Nicolas Moës (GeM Institute, Ecole Centrale de Nantes). The president of the committee was prof. Juan José Ródenas García, acting on behalf of SEMNI’s executive committee.

Figure 1:
Prof. Matteo Giacomini

In this occasion, the awardee is Prof. Matteo Giacomini (UPC´-BarcelonaTech), for his contributions to computational nonlinear solid and fluid mechanics. The Committee has valued the breadth of his research activities and the variety and extent of his national and international research collaborations. ●

SEMNI best PhD award 2021

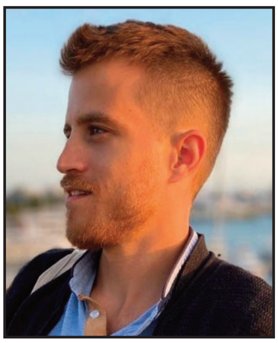


Figure 2:
Dr. David Codony

The SEMNI best PhD thesis award committee, composed by Elías Cueto (Universidad de Zaragoza, president, acting on behalf of SEMNI’s executive committee), José Antonio Sanz Herrera (University of Seville), Salvador Izquierdo (Aragon Institute of Technology, ITAInnova), and Santiago Badía (Monash University, Australia).

The recipient of this year’s best thesis award has been Dr. David Codony, for his thesis entitled “Mathematical and computational modelling of Flexoelectricity at mesoscopic and atomistic scales”, developed under the supervision of prof. Irene Arias at UPC-BarcelonaTech. ●

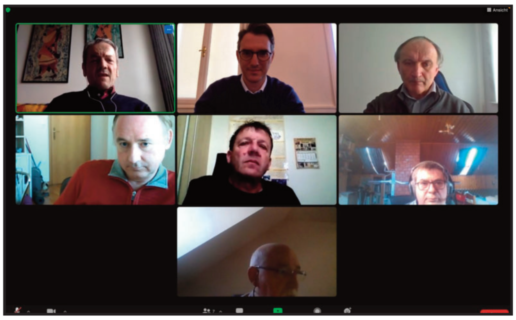
Central European Association for Computational Mechanics

for all inclusions under ***CEACM***
please contact
Adnan Ibrahimbegovic
adnan.ibrahimbegovic@utc.fr

2021 News from CEACM

URL: http://www.gf.unsa.ba/web/

The CEACM Central European Association for Computational Mechanics, has created new CEACM Awards to honor active researchers from CEACM partner countries, regrouping (in alphabetical order) Austria, Bosnia and Herzegovina, Croatia, Czech Republic, Hungary, Slovakia and Slovenia. In particular, the senior scientists are honored by newly created CEACM Prof. Mang Award and young researchers by CEACM Best Thesis Award. The highest honor by CEACM is named after its founding father Herbert Mang, Professor at TU Wien, and its first President 1992-99. The CEACM Prof. Mang Award is bestowed each year to honor an outstanding individual who has demonstrated sustained efforts in advancing either theoretical or practical aspects of computational mechanics and who provided strong leadership either in an academic environment or in different industrial applications.



The CEACM Young Researcher Award was initiated by CEACM to honor an exceptional contribution of a young scientist, who has completed his/her doctoral studies in the broad domain of Computational Mechanics within the year of the award call. The first CEACM Awards were attributed in the meeting of the CEACM Executive Board that was reunited on March 11, 2022 in online meeting (*Figure 1*).

Figure 1:
CEACM Board Online Meeting, March 11, 2022

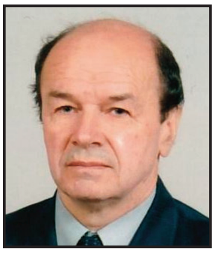


Figure 2:
Vladimír KOMPIŠ
Past-President CEACM
CEACM Prof. Mang Award

Figure 3:
Adnan Ibrahimbegovic
President CEACM
CEACM Prof. Mang Award

Figure 4:
Henrik T. Sykora
CEACM Best Thesis Award

Among the CEACM laureates are Vladimír KOMPIŠ (*Figure 2*) and Adnan IBRAHIMBEGOVIC (*Figure 3*) for CEACM Prof. Mang Award, and Henrik T. Sykora (*Figure 4*) for CEACM Best Thesis Award.

The current and future scientific activities of CEACM concern two CEACM sponsored scientific conferences. The first conference that will take place 28-30 September 2022 in Croatian City of Pula is 10th ICCSM Int. Congress of Croatian Society of Mechanics. The main contact is CEACM Board Croatian representative, Prof. Zdenko Tonković (e-mail: zdenko.tonkovic@fsb.hr). Within the framework of this meeting, there is a special session in honor of Professor Jurica Sorić, past CEACM president and longtime Croatian representative in the CEACM Board. This session, co-organized by Adnan Ibrahimbegovic, current CEACM president, Bernhard Pichler, past CEACM president, and Zdenko Tonković, is entitled 'Advanced Numerical Methods in Structural Analysis:

Recent Developments and Future Challenges', seeking to gather the contributions from different domains of expertise of Prof. Sorić. More information is given at meeting website: **www.iccsm2021.fsb.hr**.

The second conference is ECCOMAS MSF 2023, the 6th International Conference on Multi-scale Computational Methods for Solids and Fluids, which will take place in June 28-30, 2023. This conference is already 6th in a long series is jointly organized by University of Sarajevo, Academy of Sciences and Arts of Bosnia and Herzegovina and UT Compiegne. More information is given at meeting website: **www.gf.unsa.ba/eccomas-msf-2023**.

We sincerely hope to welcome you at each of these two meeting that should take place onsite, as opposed to the current practice of (virtual) online meetings, or at least in hybrid format that was used in organizing ECCOMAS MSF 2021 meeting (website: **www.gf.unsa.ba/eccomas-msf-2021**).

Towards a post-COVID era

The Japan Society for Computational Engineering and Science (JSCES) was founded as a voluntary association in 1995 following the success of the 3rd World Congress on Computational Mechanics (WCCM III), which was held in Chiba, Japan, in 1994. The society became a General Incorporated Association in 2010 owing to the hard work of our pioneers who constituted bylaws and regulations from scratch and revised and maintained them according to social needs. Thanks to our distinguished senior members, the governing structure of the JSCES has now reached a stable state. However, the COVID-19 pandemic has in the past few years enforced minimization of social activities worldwide, which of course has largely affected the activities of the JSCES as well. I believe that it is now time to return to the starting point and rethink what engineers are really for, how an academic society should act and support them, and how the society should have a relationship with the surrounding communities. It is true that the progress in the fields of computational engineering and computational mechanics is now more known to the public than before; however, it is still very important for the JSCES to promote and accelerate activities that match social and industrial needs by enhancing the information transmission capacity as one of the largest responsible incorporated associations in this field.

Under these circumstances, I would like to raise the following three main policies for my term of office:

(a) Endorsement of engineers in the fields of computational engineering/computational mechanics and promotion of international activities
The JSCES will support and promote engineers, including younger members in the fields of computational engineering/computational mechanics, through annual conferences, study groups, short courses, and summer camps.
In addition, the JSCES will manage funds aiming to support the members participating in international conferences organized by the IACM and will organize, co-organize, and support conferences, such as the WCCM and the COMPSAFE.

(b) Enhancement and reinforcement of information transmission capacity as a responsible incorporated association
The JSCES will publish high-quality transactions, academic journals, and books as one of the largest responsible incorporated associations in this field.

(c) Promotion and acceleration of activities that match social and industrial needs
The JSCES will secure transparency and fairness in its administration to be trusted by communities worldwide and cooperate with other academic societies to promote and accelerate the activities.

Figure 1: Professor Daigoro Isobe, the 14th president of JSCES

It is perhaps a difficult time now to enhance academic activities, but the JSCES will keep providing fruitful information and will actively offer physical (or virtual, but interesting) events to proceed to the next step after this pandemic.

by
Daigoro Isobe. ●

The 27th JSCES Annual Conference

The 27th JSCES Annual Conference on Computational Engineering and Science, chaired by Prof. H. Hasegawa (Shibaura Inst. Tech.), was held during June 1–3, 2022, in an in-person/online hybrid format. The in-person event was held at Akita City NIGIWAI Interchange Center AU, Akita, Japan. About 630 participants attended the conference, and about 300 papers with full lectures were presented. The two-thirds of papers were presented in the face-to-face style, and the rest were online. Fruitful discussions were exchanged in 28 organized-sessions associated with a plenary lecture, graphic awards and five luncheon seminars. Special seminars were also organized at lunch times to inspire graduate students in the field of computational mechanics by offering small talks from three young professors and researchers.

The banquet was held on the evening of the second day. The NAMAHAGE show, which is the traditional performance by demon-like beings in Akita, was demonstrated. Participants enjoyed the first in-person banquet in a long time. ●

The JSCES Grand Prize 2021

On the second day of the conference, a plenary lecture entitled "Modeling and Simulation of Complex Coupled Multifield Problems – from Basic Research to Advanced Applications" was delivered by Prof. Wolfgang A. Wall, the Funding Director of Institute for Computational Mechanics & Center for Computational Biomedical Engineering, Technical University of Munich, Germany (*Figure 2*).
In the lecture, he presented the numerical study on powder based metal additive manufacturing, the assessment of all-solid-state batteries based on the electro-chemo-thermo-mechanics framework, and the advanced basic research on tissue level to powerful full organ models.

Prof. Wolfgang A. Wall received "The JSCES Grand Prize 2021", for his outstanding contributions in the field of computational engineering and sciences, at the following ceremony (Figure 3). ●

Figure 2:
Professor Wolfgang A. Wall

Figure 3:
Ceremony of the JSCES Grand Prize 2021

conference diary planner

31 Jul - 5 Aug 2022 **WCCM-APCOM 2022 - 15th World Congress on Computational Mechanics & 8th Asian Pacific Congress on Computational Mechanics**
Venue: Yokohama, Japan *Contact:* https://www.wccm2022.org

4 - 9 Sept 2022 **AIMETA - Italian Association of Theoretical and Applied Mechanics**
Venue: Palermo, Sicily, Italy *Contact:* https://www.aimeta.it/

12 - 14 Sept 2022 **CMN 2002 - Congress on Numerical Methods in Engineering**
Venue: Las Palmas, Spain *Contact:* https://congress.cimne.com/cmn2022/

25 - 27 Sept 2022 **MFEM2020 - Meshfree and Novel Finite Elements with Applications**
Venue: Berkeley, CA, USA *Contact:* mfem2020.usacm.org

6 - 9 Nov 2022 **IGA2022 - USACM Thematic Conference - Isogeometric Analysis**
Venue: Banff, Canada *Contact:* iga2022.usacm.org

1 – 4 Nov 2022 **MECOM 2022 - XXXVIII Argentine Congress on Computational Mechanics**
Venue: Bahía Blanca, Argentina *Contact:* https://amcaonline.org.ar/mecom2022/

2 - 4 Nov 2022 **5th AfriComp - 5th African Conference on Computational Mechanics**
Venue: Cape Town, South Africa *Contact:* https://africomp.info/

6 - 9 Nov 2022 **IGA 2022 - 10th International Conference on Isogeometric Analysis**
Venue: Banff, Canada *Contact:* iga2022.usacm.org

21 - 25 Nov 2022 **XLIII CILAMCE - XLIII Ibero-Latin American Congress on Comp Methods in Engineering**
Venue: Foz do Iguaçu, Brazil *Contact:* https://www.cilamce.com.br/

6 Dec 2022 **11th JACM Computational mechanics Symposium**
Venue: Japan *Contact:* https://ja-cm.org/index-j.html

5 - 8 March 2023 **KomPlas Tech 2023 - XXVIII Conference on Computer Methods in Materials Technology**
Venue: Poland *Contact:* https://www.eccomas.org/conferences/

30 - 31 March 2023 **SYMCOMP 2023 - VI Int Conf on Numerical 6 Symbolic Computation: Dev & Applications**
Venue: Évora, Portugal *Contact:* https://www.eccomas.org/conferences/

25 - 28 April 2023 **CFC 2023 - 22nd IACM Computational Fluids Conference**
Venue: Cannes, France *Contact:* https://cfc2023.iacm.info/

30 May - 1 June 2023 **Math 2 Product (M2P) - 1st Emerging Tech in Comp Science for Industry, Sustainability & Innovation**
Venue: Taormina (Messina), Italy *Contact:* https://m2p2023.cimne.com/

1 - 3 June 2023 **EUROGEN 2023 - 15th Int Conf on Evolutionary & Deterministic Methods for Design, Optimization & Control**
Venue: Chania, Crete, Greece *Contact:* https://www.eccomas.org/conferences/

5 - 7 June 2023 **COUPLED PROBLEMS 2023 - Int Conf on Coupled Problems in Science & Engineering**
Venue: Chania, Crete Island, Greece *Contact:* https://coupled2023.cimne.com/

12 - 14 June 2023 **COMPDYN 2023 - IX Int Conf on Comp Methods in Structural Dynamics & Earthquake Engineering**
Venue: Athens, Greece *Contact:* https://www.eccomas.org/conferences/

12 - 14 June 2023 **UNCECOMP 2023 - V Int Conf on Uncertainty Quantification in Computational Sciences & Eng**
Venue: Athens, Greece *Contact:* https://www.eccomas.org/2022/04/01/thematic-conference-2023/

18 - 21 June 2023 **IGA 2023 IX International Conference on Isogeometric Analysis**
Venue: Lyon, France *Contact:* https://www.eccomas.org/conferences/

19 - 21 June 2023 **ADMOS 2023 - International Conference on Adaptive Modeling & Simulation**
Venue: Gotheburg, Sweden *Contact:* https://admos2023.cimne.com/

21 - 23 June 2023 **CFRAC 2023 - The 7th Int Conf on Comp Modeling of Fracture & Failure of Materials & Structures**
Venue: Prague, Prague, Czechia *Contact:* https://www.eccomas.org/conferences/

25 - 27 June 2023 **MSF 2023 - 6th International Conference on Computational Methods forSolids & Fluids**
Venue: Sarajevo, Bosnia-Herzegovina *Contact:* https://eccomas.gf.unsa.ba/msf-2023/

27 - 29 June 2023 **MARINE 2023 - X International Conference on Computational Methods in Marine Engineering**
Venue: Madrid, Spain *Contact:* https://marine2023.cimne.com/

25 - 27 June 2023 **MSF 2023 - V International Conference on Computational Methods for Solids & Fluids**
Venue: Sarajevo, Bosnia-Herzegovina *Contact:* https:// eccomas.gf.unsa.ba/msf-2023

3 - 6 July 2023 **SMART 2023 - IX Conference on Smart Structures and Materials**
Venue: Patras, Greece *Contact:* https://www.eccomas.org/conferences/

5 - 7 July 2023 **ICCCM 2023 - 7th International Conference on Computational Contact Mechanics**
Venue: Torino, Italy https://www.eccomas.org/conferences/

18 - 21 July 2023 **CMP4 2023 - Computational Modelling of Multi-Uncertainty & Multi-Scale Problems**
Venue: Porto, Portugal *Contact:* https://www.eccomas.org/conferences/

23 - 27 July 2023 **17th U. S. National Congress on Computational Mechanics**
Venue: Albuquerque, NM, USA *Contact:* 17.usnccm.org

24 - 28 July 2023 **MULTIBODY 2023 - ECCOMAS Thematic Conference on Multibody Dynamics**
Venue: Lisboa, Portugal *Contact:* https://www.eccomas.org/conferences/

25 - 29 July 2023 **USNCCM16 - 16th U.S. National Congress on Computational Mechanics**
Venue: Chicago, Illinois Contact: http://16.usnccm.org/

26 - 28 July 2023 **SIM-AM 2023 - IV International Conference on Simulation for Additive Manufacturing**
Venue: Munich, Germany *Contact:* https://www.eccomas.org/conferences/

20 - 23 Aug 2023 **M-FET 2023 - III Modern Finite Element Technologies – Mathematical & Mechanical Aspects**
Venue: Mülheim, Germany *Contact:* https://www.eccomas.org/conferences/

5 - 7 Sept 2023 **COMPLAS 2023 – XV!! Int. Conference on Computational Plasticity**
Venue: Barcelona, Spain *Contact:* https://complas2023.cimne.com/

24 - 27 Sept 2023 **2nd IACM Mechanistic Machine Learning & Digital Twins for Computational Science, Eng. & Technology**
Venue: El Paso, TX, USA *Contact:* https://www.utep.edu/engineering/mmlde/index.html

2 - 4 Oct 2023 **Structural Membranes 2023 – X! Int Conference on Textile Composites & Inflatable Structures**
Venue: Valencia, Spain *Contact:* https://structuralmembranes2023.cimne.com/

9 - 11 Oct 2023 **PARTICLES 2023 - VII International Conference on Particle-based Methods**
Venue: Milano, Italy *Contact:* https://congress.cimne.com/particles2023/

10 - 13 Oct 2023 **CMCS 2023 - II Int Conf on Computational Modeling of Complex Materials Across the Scales**
Venue: Eindhoven, Netherlands *Contact:* https://www.eccomas.org/conferences/

21 - 26 July 2024 **WCCM/PANACM - 16th World Congress on Comp Mechanics & 4th PANACM Congress**
Venue: Vancouver, Canada *Contact:* https://www.cacse-accsg.ca/