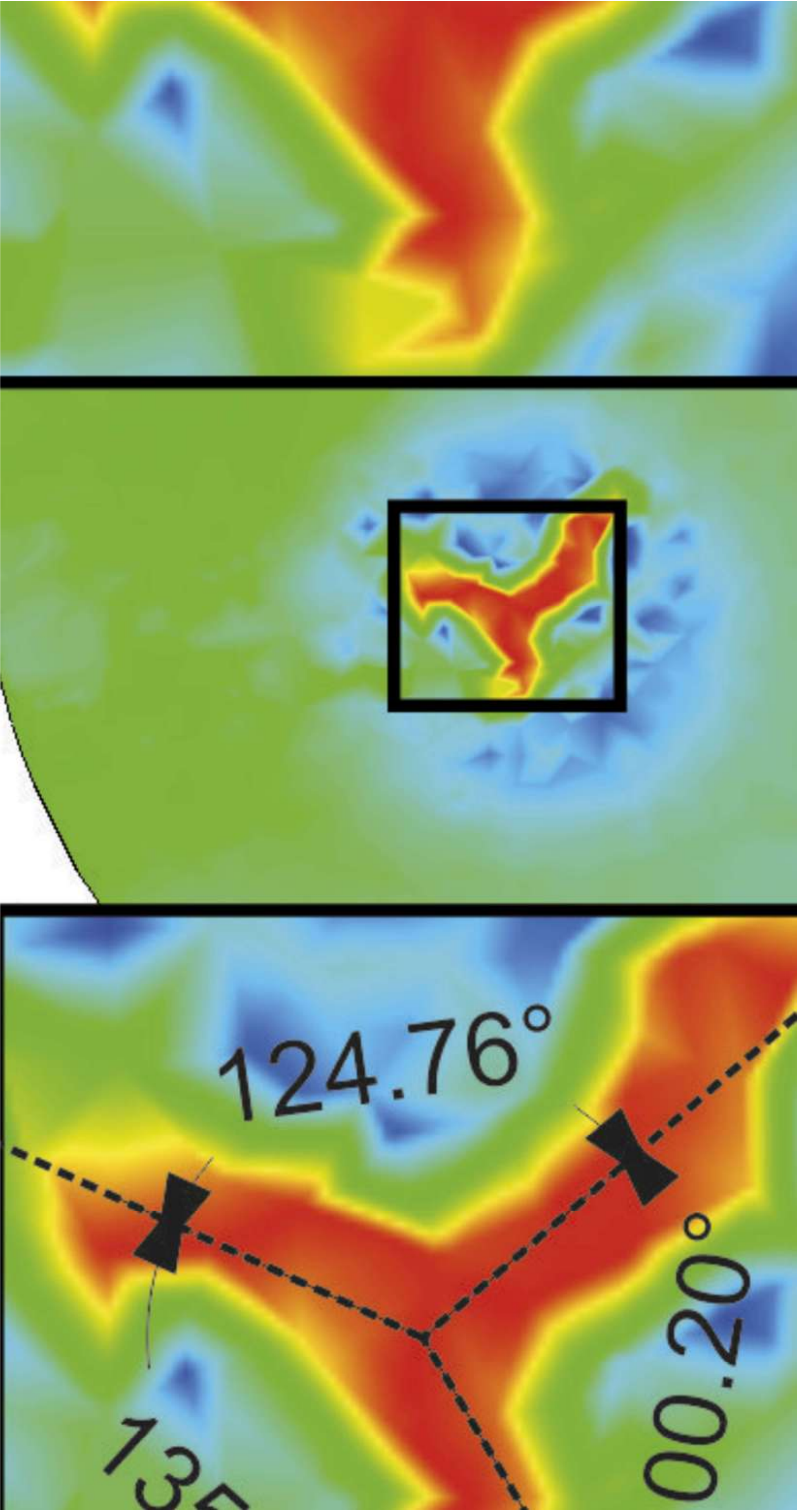
iacm expressions



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contents

editorial

High In the last issue of Expressions we highlighted that cloud-based software services are growing fast in industry and academia thanks to highly flexible and customizable deployment methods. The so-called SaaS (software-as-a-service) procedure allows users to connect to and use cloud-based applications over the Internet. Some common early examples of SaaS are email, calendars and office tools. The list has grown exponentially in recent times to include all types of cloud-based simulation services provided by most software vendors, including data input and storage and on-line visualization of numerical results.

SaaS offers a comprehensive software solution that is purchased from a cloud service provider using a pay-per-use model. You rent the use of a computer code for your organization and users connect to it through the Internet, usually with a web browser. All the underlying infrastructure, middleware, software and application data are located in the provider's data center. The service provider manages the hardware and software and, with the appropriate service contract, will also guarantee the availability and security of the application and its data. SaaS allows an organization to start up and run software applications with a minimum initial cost.

The bottom line is that the cloud offers speed, ease and completeness of access and data availability. Scientists in the laboratory, or engineers in face-to-face or teleconferenced client meetings can access databases on the fly and make more informed choices on the next iteration in the computational design or manufacturing of new products or processes.

The benefits of cloud solutions offered as SaaS are manifold, and include seamless scalability, fast implementation and configuration, lower capital investment, and anywhere, anytime, anyhow accessibility. The SaaS model also represents a lifeline for some smaller startup companies, giving them the chance to install an optimized informatics architecture that is backed by vendor maintenance and the security of the major global giants such as Amazon Web Services (AWS), Microsoft Azure and Google Cloud.

Cloud-hosted platforms allow research organizations to focus time and resources on key scientific projects and business applications, rather than on managing their IT infrastructure. Also, the increasing security of the data stored in the cloud offered by SaaS providers has got users over the hurdle of where their data is going, and convinced them that the cloud is secure.

Cloud computing is an increasingly popular SaaS model which allows the user to access a catalog of standardized computer simulation services and respond with them to their computational needs, in a flexible and adaptive manner, in case of unforeseeable demands or peaks of work, paying only for the consumption made, or even free of charge in the case of suppliers that are financed through advertising or non-profit organizations.

Some attribute the scientific concept of cloud computing to John McCarthy, who proposed the idea of computing as a public service, similar to service companies dating back to the 1960s. In 1960 he said: "One day computing can be organized as a public service"

George Gilder said in 2006: "The desktop PC is dead - welcome to the Internet cloud, where a huge number of facilities around the globe will store all the data you can ever use in your life."

The key factors that have allowed cloud computing to evolve have been, according to the British pioneer on cloud computing Jamie Turner, the virtualization technologies, the development of the universal high-speed bandwidth and universal standards of software interoperability. Turner added: "As cloud computing expands, its reach goes beyond a handful of Google Docs users - we can only begin to imagine its range of applications and scope - almost anything can be computed in the cloud." .

Cloud computing has come to stay, at least for a long time, and we, the members of the computational mechanics community, should take good note of it. Thus, when we formulate, design and implement the next generation of simulation codes for solving practical problems, we should take into account that the input data, the simulation analysis and the visualization of the results will be managed in the cloud.

Eugenio Oñate
Editor of IACM Expressions

Verification and Validation of Engineering Problems in Computational Mechanics

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Verification and Validation (V&V) is a methodology to enhance the credibility of engineering simulation. Technical guides and standards have been published for V&V. There are two categories of the V&V documents: V&V for Modeling and Simulation (V&V for M&S) and V&V for Quality Management (V&V for QM). Bayesian optimization is expected to estimate the uncertainty in the prediction of V&V for M&S.

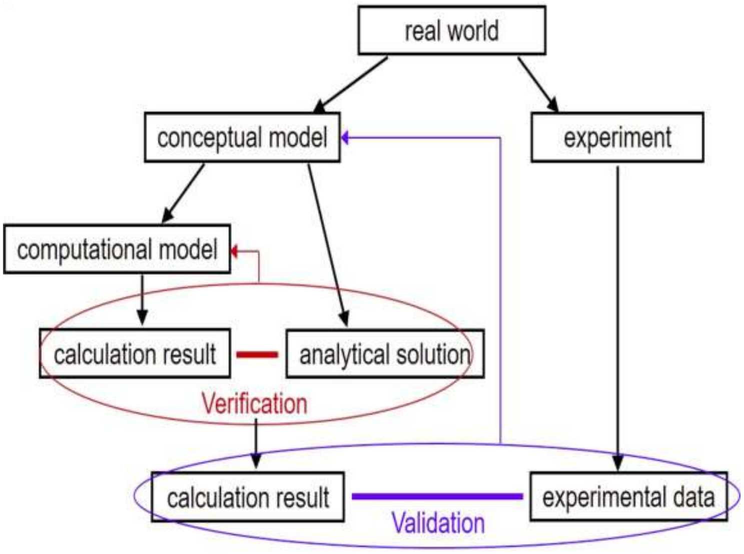
Why is V&V Required for Engineering Simulation?

Computational mechanics has grown to be used widely in industry. When the simulation result is practically used for products, its credibility should be rigorously quantified. Quality management is commonly required for any products. However, engineering simulation has its own difficulty that the calculation result cannot be tested, unlike a car or a camera, after it is produced. Thus, the process to obtain the calculation result should be managed. V&V for the engineering simulation is a methodology to improve the credibility by making the standard process [1].

Specialists of computational mechanics are expected to explain the credibility of their calculation results to the customers, supervisors, decision makers, public, etc. V&V is a common language for this communication.

In 2011, there was a disaster of tsunami in Japan. Three nuclear reactors were molten in the Fukushima Dai-ichi Nuclear Power Station due to tsunami flooding and subsequent blackout. The main cause of this severe accident is the delay of countermeasures against tsunami [2]. The company had a simulation result of the tsunami height of 15.7m in 2008 using a new finding of the tsunami sources, though the countermeasures had not been enhanced from 5.7m in the past calculation. The actual tsunami height was 15m in 2011. There were uncertainties in the simulation in 2008, which makes the company unwilling for the quick enhancement of the countermeasures. V&V had been more required for the assessment of uncertainties and the communication between the specialists and the decision makers.

Figure 1:
Verification and Validation for Modeling and Simulation (V&V for M&S) [1]



V&V for M&S

A simplified procedure of Verification and Validation for Modeling and Simulation (V&V for M&S) is shown in *Figure 1*. The top of the procedure is "real world" which is the intended use of the engineering simulation: for example, safety of the driver in case of a car crash accident on the public road. The "real world" is modeled for simulation: for example, solid mechanics involving both elastic and plastic deformation. A set of governing equations are employed as the "conceptual model". These governing equations are discretized and a computer program is made. This program is called "computational model". A calculation result is obtained by executing the program with input data.

Verification is the process of determining that a computational model accurately represents the conceptual model. This is equivalent to evaluate the errors when we use the computational model: mistakes in programming and errors derived from the spatial mesh, the time step, convergence of iterations etc. The verification is usually carried out by comparing the calculation result and the analytical solution.

Validation is the process of determining the degree to which the conceptual model is an accurate representation of the real world from the perspective of the intended use of the engineering simulation.
The validation is usually carried out by comparing the calculation result and the experimental result. Uncertainties involved in the calculation result are assessed. They come from the boundary conditions, physical properties, neglecting physics in the conceptual model, etc. Some of the physics can be neglected for the intended use; for example, fluid dynamics may be neglected for the car crash accident. However, to show the validity of the neglecting can be confirmed by the comparison with the experiment.

Technical guides and standards of V&V for M&S have been published from the American Society of Mechanical Engineers (ASME) [3-5]. The Atomic Energy Society of Japan (AESJ) has published a guide of V&V for M&S [6] in the field of nuclear engineering.

V&V for QM

Another category is Verification and Validation for Quality Management (V&V for QM). The basic technical document is ISO 9001 [7]. The additional requirements to ISO 9001 for the engineering simulation were published by NAFEMS [8] and the Japan Society for Computational Engineering and Science (JSCES) [9].

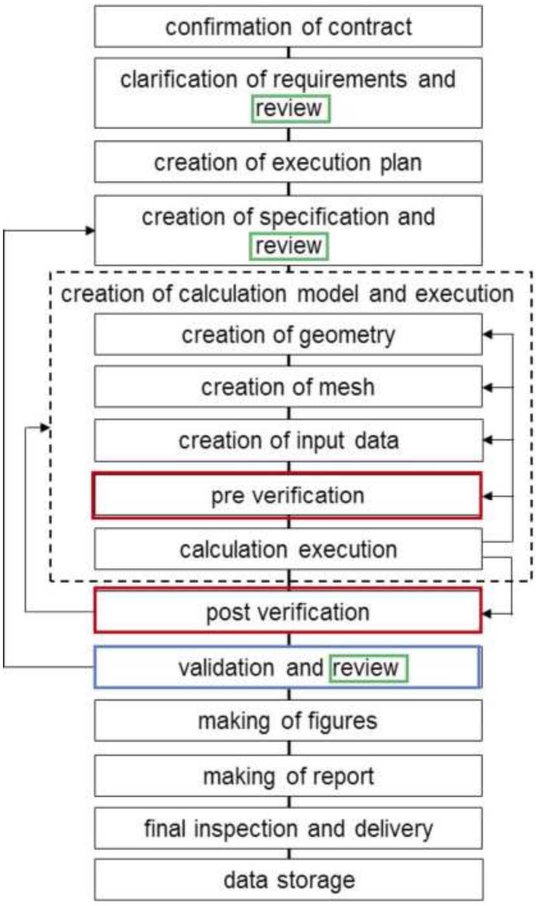


Figure 2:
Standard procedure for engineering simulation [10]

Figure 2 provides the standard procedure of engineering simulation described in [10]. A task starts by the requirements of a customer. The specification is determined and the calculation is executed. Verification is the process of confirmation that the calculation is correctly executed as the specification. If not, the input conditions are revised to be correct and the calculation is executed again. Validation is the process that the task is completed within the requirements of the customer. If not, the specification is modified and additional calculation is executed. Review, which is the check of the supervisor, is requested in three processes: creation of requirements, creation of specification, and validation. Four application examples are provided in [11].

V&V for QM is the procedure for engineering simulation to enhance the credibility as the business. We need to care that V&V for QM requires the knowledge of computational mechanics (competence) for the specialists as well as the formalism. Both of two V&Vs are necessary to enhance the credibility of engineering simulation.

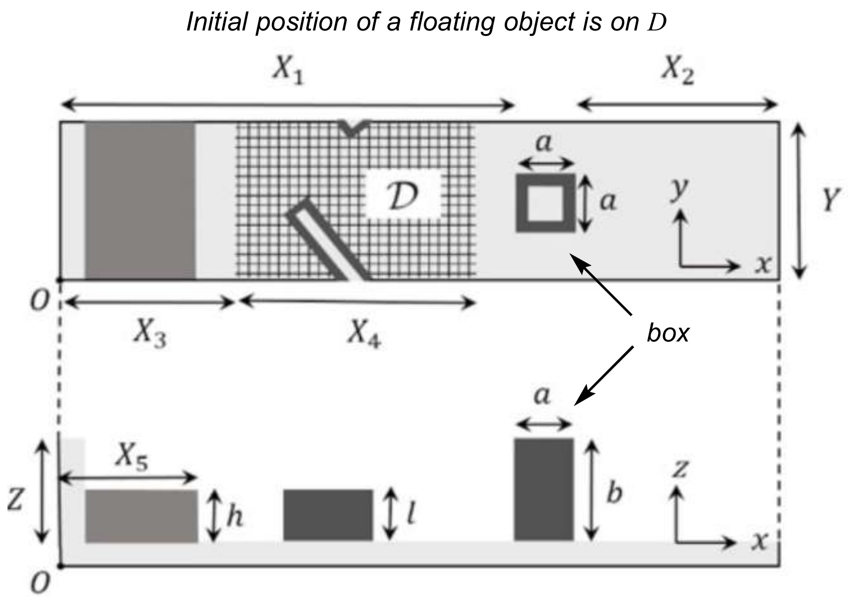


Figure 3:
Water spreading with a floating body

Application of Bayesian Optimization to Uncertainty Quantification

One of the arguments concerning V&V for M&S is "prediction". Engineering simulation is usually used for predictions at unknown conditions. Validation directly shows the validities at the limited cases. For instance, V&V-10 [3] positively accepts predictions as saying that "predictions can and should be tested for trustworthiness by the accumulation of evidence". However, V&V-20 [4] holds a negative position as saying "consideration of solution accuracy at points within a domain other than the validation points is a matter of engineering judgement".

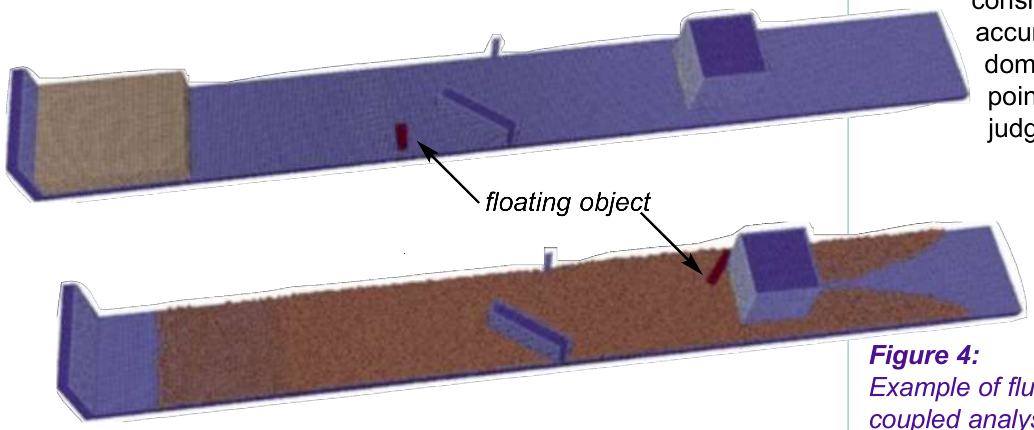


Figure 4:
Example of fluid-rigid body coupled analysis

One approach of predictions is Bayesian optimization [12]. *Figure 3* shows a calculation example using the MPS (Moving Particle Semi-implicit) method for water spreading with a floating object. The initial position of the floating object can be located on the left area of 1.28 x 0.30 [m] with 0.04 and 0.02 [m] spacing in *x* and *y* directions, respectively. A rectangular water column is located on the left side and collapses at t=0 [s]. The floating body is treated as a rigid body. Fluid-rigid body coupled analysis is carried out.

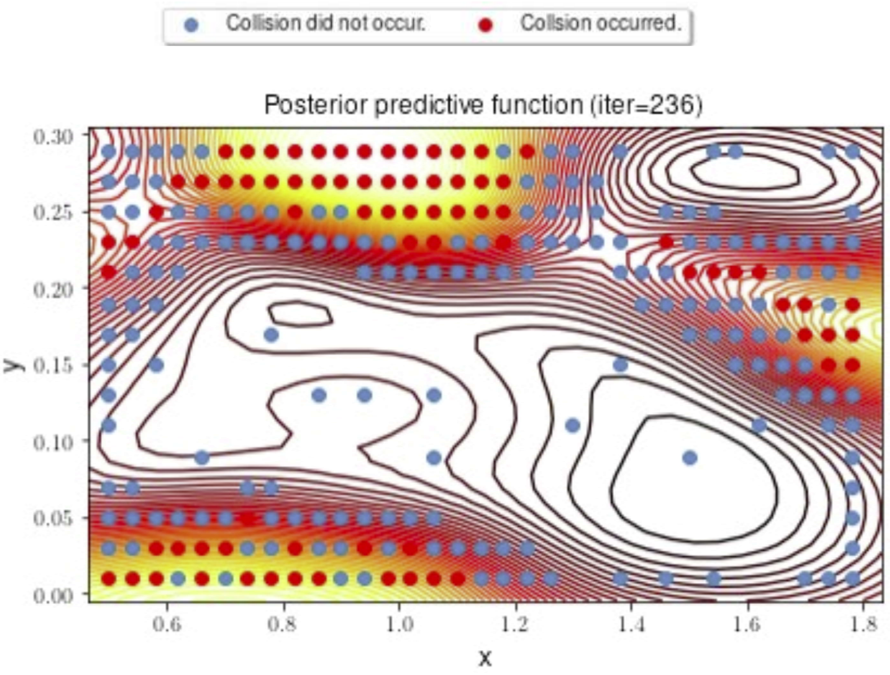


Figure 5:
The initial positions of the floating object and calculated collision with the box after 236 iterations

A simulation example is shown in *Figure 4*. In this case, the floating object collides with the box located in the right. The problem is to search the initial positions where the floating object collides with the box. The initial 10 positions are randomly selected, the fluid-rigid body coupled analyses are carried out, and the collisions are judged. If collision occurs, 1.0 is given to *c*. If it does not occur -1.0 is given to *c*. The next initial position is determined as the estimated maximum *c* with uncertainty. The Gaussian process regression is used for the estimation of *c* and its uncertainty.

Figure 5 shows the simulation results of collision or non-collision after 236 iterations. We can see three regions where the collision occurs. It should be noticed that some of the positions for non-collision are searched as well as most of the positions for collision are searched. This is because uncertainty is estimated. A large uncertainty may lead to estimation of a large value of *c*, which may cause the next choice of the position in the non-collision region.

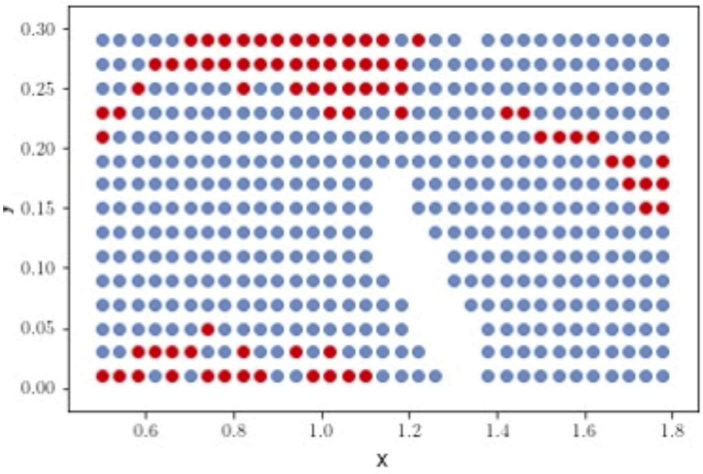


Figure 6:
Collision and non-collision positions of all cases

X_1, X_2, X_3, X_4, X_5	1.8, 1.0, 0.5, 1.28, 0.4 [m]
Y, Z	0.3, 0.2 [m]
a, b, h, l	0.2, 0.2, 0.1, 0.1 [m]
floating object	0.02x0.02x0.12 [m]

Table 1:
Dimension of the geometry

All the simulation results of 468 positions are depicted in *Figure 6*. We can see good agreement between *Figures 5 and 6*, three regions for collision. This means that we can reduce the simulation cases by using Bayesian optimization. ●

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Predictive 3D Micro Cracks Simulations in Civil Engineering Materials Microstructures

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Prediction of fracture resistance in concrete and cementitious materials is of huge interest in engineering and has been a topic of research since several decades. Recently, several techniques have reached maturity and their conjunction opens the route for a breakthrough in this area: the democratization of experimental 3D imaging techniques [14] at micro scale, in-situ experimental techniques, and the development of new numerical simulations methods for fracture such as the phase field method [1-4]. In contrast to classical modeling approaches, such techniques allow studying fracture in complex materials directly from the micro scale, and then better understanding the microstructural damage mechanisms which will be the basis for future more predictive macroscopic fracture models. In a series of works [5-9], we have proposed new studies of fracture in concrete materials by combining these different above mentioned techniques and have shown that predictive models can be obtained. More specifically, experimental 3D micro tomography combined with in-situ testing has been used and combined with the phase field method for fracture. The main methods and results are presented in the following.

Phase field method for fracture simulation

Until recently, one obstacle for studying fracture at the microscale in heterogeneous materials lay in the difficulty to simulate initiation and propagation of complex 3D micro cracks networks in complex 3D geometries. A drastic progress has been achieved with the development of the phase field method for fracture (see e.g. [1-4, 10,11] and the references therein). The crack propagation modeling and simulation method based on the variational approach to fracture as proposed by Bourdin, Marigo and Francfort [12,13], and developed in an efficient algorithmic framework by Miehe et al. [3], allows circumventing several well-known issues in fracture simulation and offer many advantages such as:
(a) a simple numerical framework involving classical discretization techniques like usual finite elements;
(b) mesh-independence;
(c) the convergence with respect to the mesh size;
(d) the possibility to handle initiation, propagation and merging of a large number of micro cracks in 3D complex configurations;
(e) a great numerical robustness and efficiency. This technique is especially well adapted to the modeling of cracking in microstructural models directly obtained by images e.g. through micro- CT tomography, which form grids of voxels.

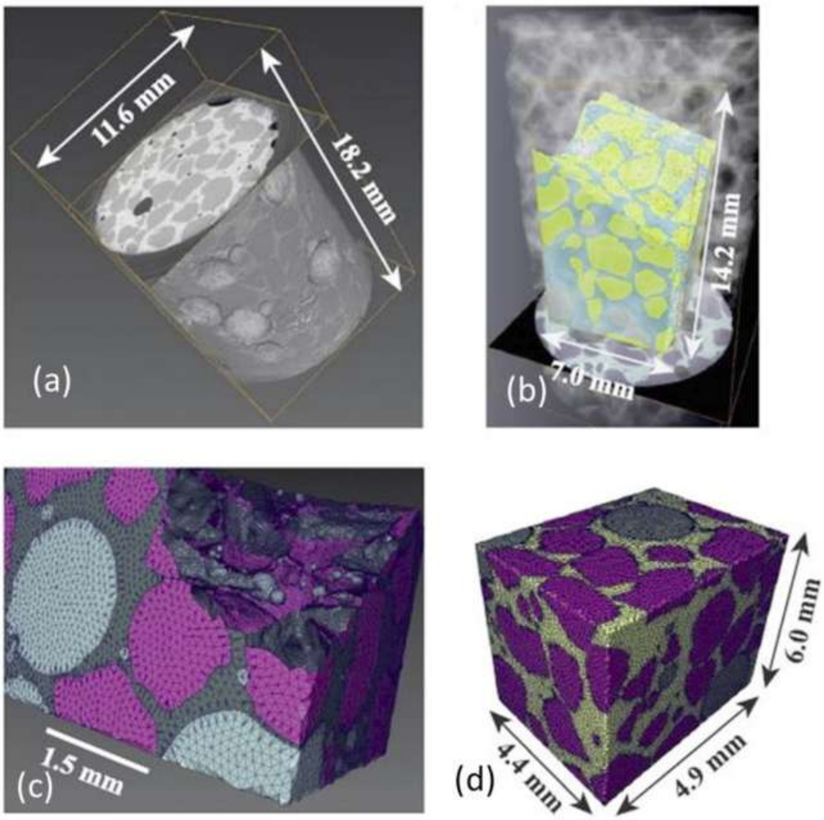

Figure 1:
(a) Full CT image of a lightweight concrete;
(b)–(c)–(d) views of an unstructured mesh constructed from the CT image.
NOTE: image taken from reference 7

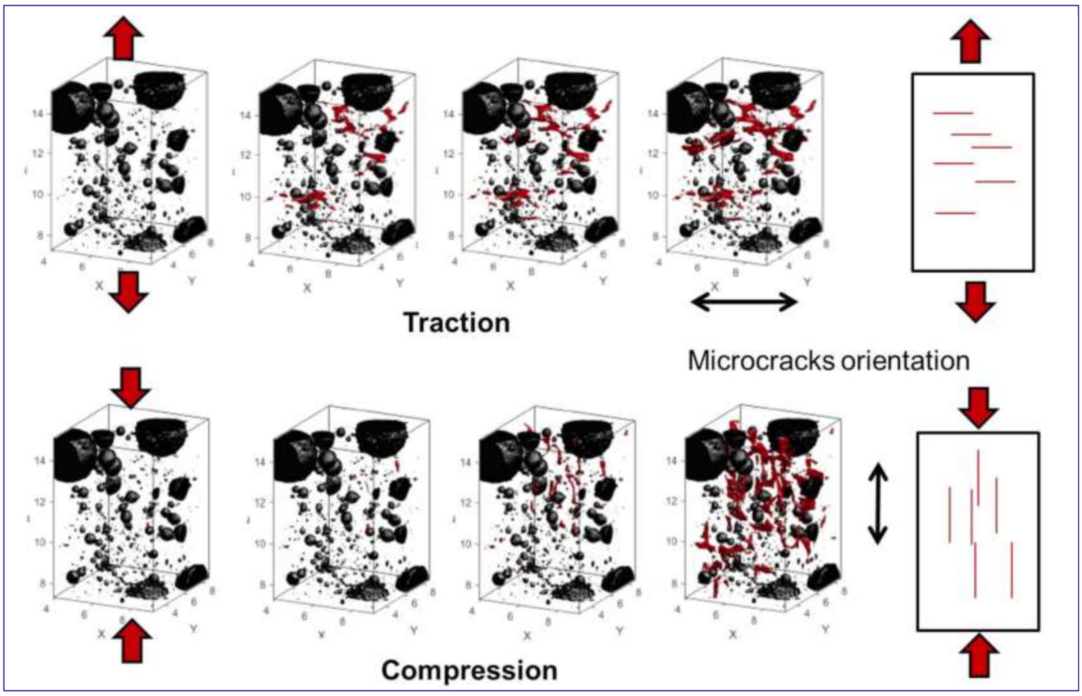

Figure 2:
High resolution of micro crack initiation and propagation in realistic concrete microstructure: black phase denotes pores. Red phases denote micro cracks. Sand grains are not depicted for the sake of clarity. Upper row: traction simulation; lower row: compression simulation. The simulation is able to reproduce the main orientation of micro cracks in concrete depending on the compression/traction regime. NOTE: Image adapted from reference 7

Micro-tomography image-based microstructural models

Instead of using idealized models of microstructures, one key development here is the direct use of images obtained by X-ray computed micro tomography (XR-µCT) to construct the meshes of microstructures. The meshes can be either obtained from direct projection of voxel phases on a regular mesh (which might be costly) or obtained by conversion of grey-level images into unstructured meshes (which might save elements by possible local refinement). An illustration of the construction of an unstructured mesh from a concrete microstructure is depicted in *Figure 1*. Examples of simulations (*Figure* 2) in 30 million-element Finite Element mesh shows that combining phase field method and image-based models allows reproducing e.g. the expected orientation of micro cracks in concrete with respect to the loading [7].

Predictive simulations in heterogeneous plaster samples

In *Figure 3 (a-f)*, we provide two examples of predictive crack networks in realistic heterogeneous sample models. The first case involves a plaster model sample

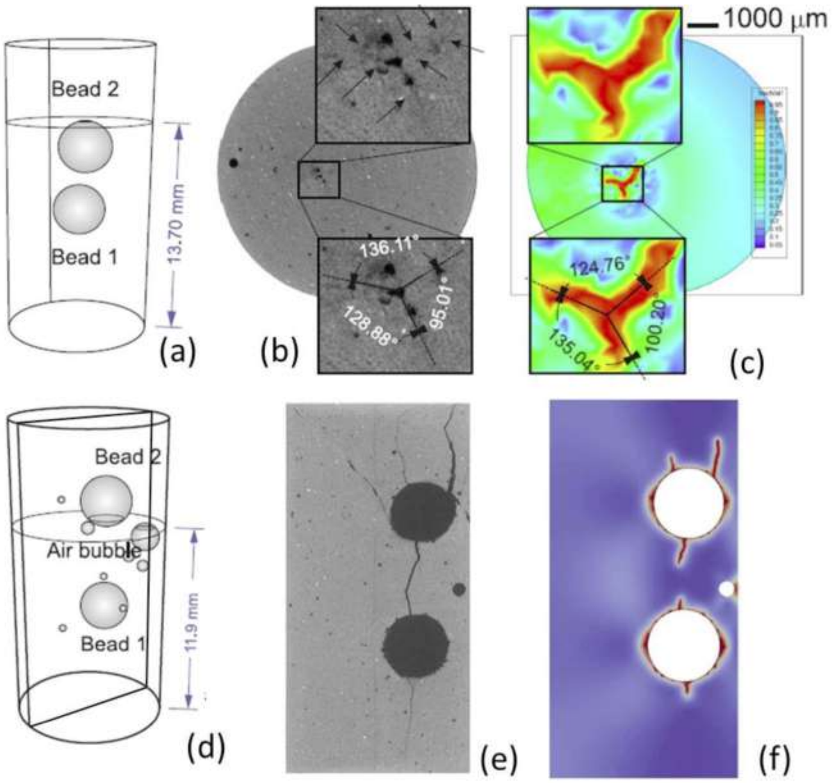

Figure 3:
Sample 1: crack path comparison in a lightweight plaster under compression: (a) position of the plane of study; (b) experimental result and (c) simulation result. Sample 2: crack path in a sample with several sizes of porosities: (d) position of pores experimental crack network (f) and simulation. NOTE: image taken from reference 6

embedding Expanded PolyStryrene (EPS). XR-µCT combined with in-situ testing and image processing based on Digital Volume Correlation (DVC) [6,14] have been used to experimentally the evolution of 3D crack network during the test. The initial mesh of the studied sample has been constructed by the direct use of the XR-µCT images. Remarkably, the complex cracks networks are accurately reproduced by the numerical simulations.

Another case is shown in Figure 3 (d-f), where the sample here contains several sizes of porosities.

> “ *Combining realistic image-based microstructural models and phase field fracture simulation methods allows prediction of complex micro crack networks never performed before.* ”

Predictive microstructural cracking in concrete

In the next example, a lightweight concrete material including pores, sand grains and cement paste (see *Figure 1*) is investigated. To analyze with high resolution the cracking process at the micro scale, a subdomain is analyzed during the in-situ testing procedure combined with XR-µCT (see *Figure 4*).

Then, by means of DVC, the experimental displacement boundary conditions are applied on the boundary of the sample, which contains a mesh obtained from the image. Results in *Figure 5* show very predictive crack development at the microscale and for the same loads as in the experiment.

Inverse identification approaches

Finally, due to their very predictive character, these methods can be used for inverse identification of microstructural damage parameters which could hardly be directly measured. Using the numerical crack propagation model, the microstructural parameters are optimized so as to reproduce the experimental data. An illustration of such process in the sample of *Figure 3 (a)* is depicted in *Figure 6*.

Conclusions

We have presented new methodologies combining numerical simulations and experiments for predicting microcracking damage in civil engineering materials. One key feature is the use of the phase field method combined with image-based microstructural models. We have shown the high predictability of such simulations, which might be a route for the construction of predictive macro models in civil engineering materials.

Acknowledgements

This work has benefited from a French government grant managed by ANR within the frame of the national program Investments for the Future ANR-11-LABX-022–01. ●

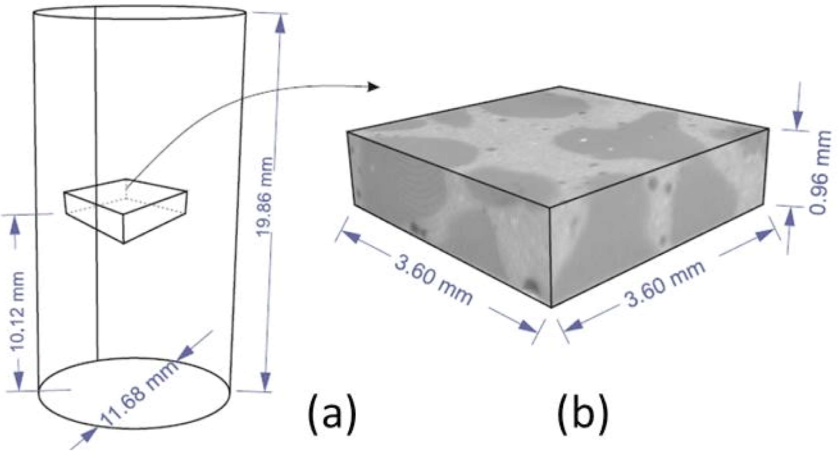

Figure 4:
Geometry of the studied sub-volume: (a) location in the sample; (b) XR-µCT images of the sub-volume.
NOTE: image taken from reference 6

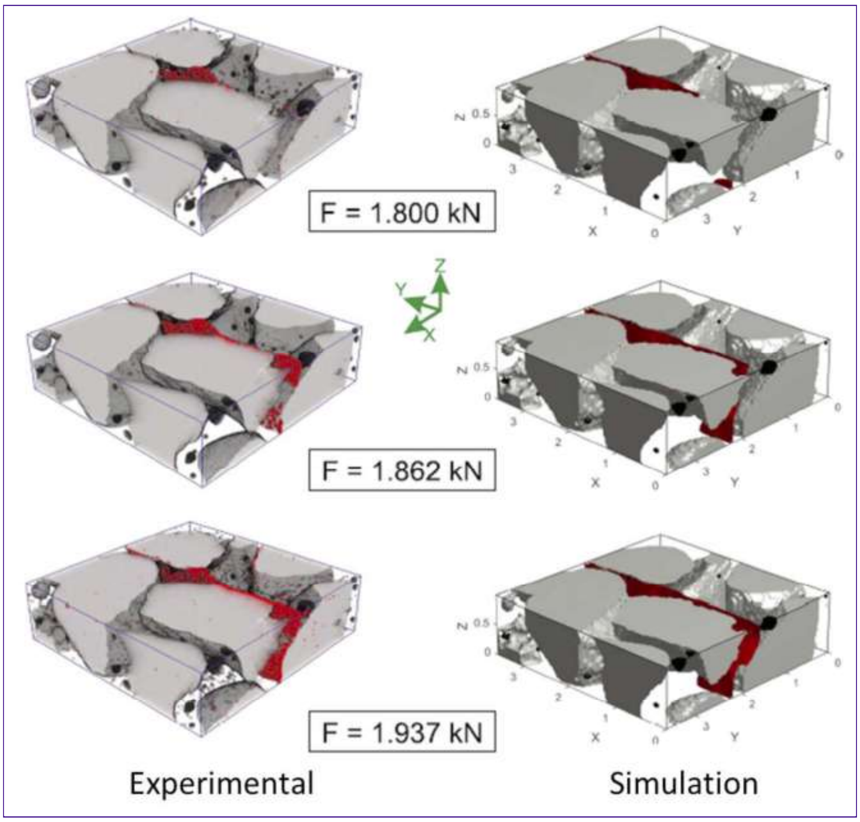

Figure 5:
Comparison between experimental crack obtained from micro tomography and from phase field method of the lightweight concrete sample in a sub-volume for several loads.
NOTE: image taken from reference 6

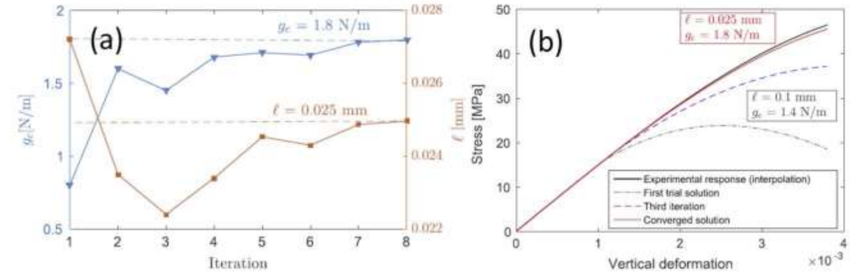

Figure 6:
Evolution of the parameters l and g_c during the inverse identification and (b) evolution of the predicted response with the evolution of the identified material parameters and comparison with the fitted experimental curve.
NOTE: image taken from reference 6

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Basis Adaptation for Polynomial Chaos Expansions

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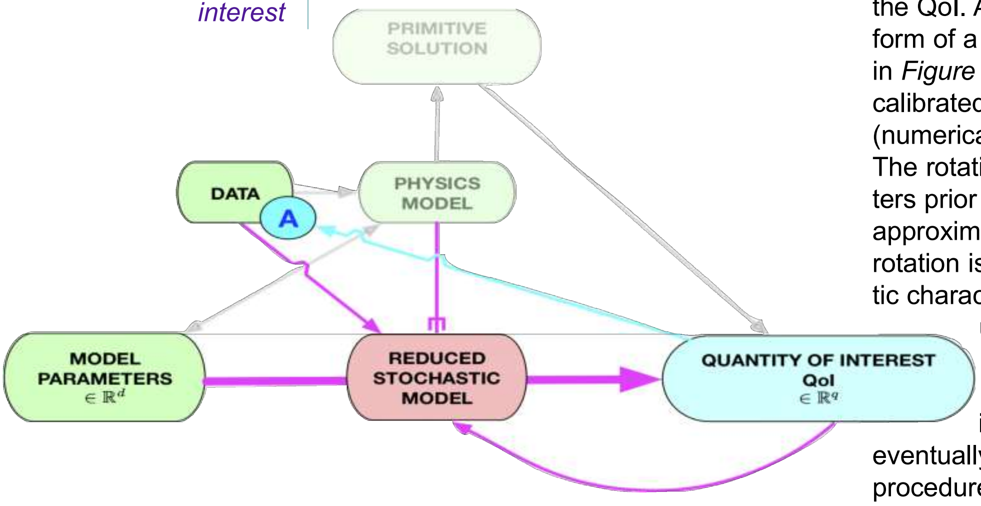
Computational models are approximations to mathematical equations which themselves attempt to describe physical reality in a sensible and useful manner. The measure to which the mathematical equations are being approximated has lent itself, with significant success, to standard tools from numerical and functional analysis, resulting in a treasure trove of theorems, algorithms, and procedures for approximating, to within target accuracy, an ever growing array of deterministic problems. Gauging the suitability of the mathematical model as a surrogate to physical reality, has traditionally been approached using tools of probability theory, necessitating the construction of models that enable the interplay between physical premises and experimental evidence. Fundamentally, probabilistic models contemplate simultaneously all possible scenarios that are consistent with prior knowledge while not contradicting available evidence. A multifold increase in computational burden necessarily ensues as a multitude of scenarios are generated and tested against available knowledge. This increase in computational cost is fundamental to probabilistic models and is expected. In recent years, polynomial chaos expansions (PCE) have emerged as a viable formalism for constructing prior probabilistic models that are constrained to mathematical representations of physical phenomena (Ghanem, 1991, Ghanem and Red-Horse, 2017). Constraining these representation with posterior evidence has also been explored (Sargsyan et.al, 2014), resulting in a comprehensive PCE-based probabilistic agenda. The PCE construction provides a convergent map between input and output of computational models, and as such the associated computational cost grows exponentially with the number of input parameters.

Figure 1: Two workflows for predicting a quantity of interest



Polynomal Chaos Adaption

This "curse of dimensionality" is inherited from multi-variate approximation procedures and reflects the complex dependence of the primitive solution of the mathematical problem on data. This solution is typically defined over the whole spatial domain, and over time intervals of interest. Often in engineering problems, however, a handful of scalar quantities, rather than full-field solutions, are of interest. A recent PCE-based stochastic reduced-order modeling (SROM) procedure (Tipireddy and Ghanem, 2014) permits these quantities of interest (QoI), rather than the full-field solution, to control the computational complexity of a given probabilistic problem. Figure 1 shows two paradigms for computing QoIs. The standard paradigm, (going through the de-emphasized green boxes) evaluated the QoI by post-processing the primitive solution to the physics problem. The SROM approach follows the purple arrows, directly constructing an approximation of the QoI that is sufficiently constrained by the physics-model. The construction of the SROM is informed by a low-order approximation of the QoI, and is thus adapted to the QoI. An adaptation parameter, in the form of a rotation matrix (denoted by **A** in *Figure 1)*, is introduced, which must be calibrated from available information (numerical or laboratory experiments). The rotation **A** acts on the input parameters prior to performing a high-order PCE approximation of the QoI. A well-adapted rotation is such that an accurate probabilistic characterization of the QoI is achieved using the first few "rotated" dimensions. As the number of retained "rotated" dimensions is increased, the exact solution is eventually recovered. A number of procedures for learning the adaptation **A**

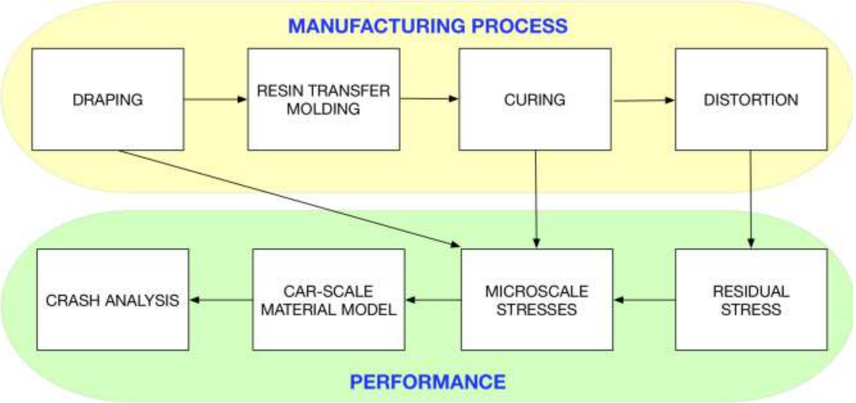


Figure 2:
Schematic of a typical engineering process: Manufacturing and performance prediction of composite structures

have been proposed to-date all of which are based on a Gaussian-Hermite PCE construction and leverage the invariance of Gaussian measures under rotations. Non-Gaussian input parameters are first mapped into their Gaussian pre-images, using Rosenblatt transforms or similar measure transport maps (Marzouk et.al, 2017), before proceeding with the adapted PCE approximation. The most elementary and simplest adaptation is referred to as the *Gaussian Adaptation* and proceeds as follows: the first order PCE approximation of the QoI is identified with the first row of the rotation matrix **A**. Subsequent rows are first populated with 1 at the location corresponding to the sensitivity rank of that row, and zero otherwise. A rotation matrix is then obtained from this initial matrix through a Gram-Schmidt orthogonalization procedure (Tipireddy and Ghanem, 2014 and Ghauch et.al, 2018). A high-order PCE of the QoI is then obtained in the reduced “rotated” directions. A second procedure constructs simultaneously the rotation **A** and the high-order/reduced-dimension PCE of the QoI through a staggered optimization process involving a least squares to find the rotation for given coefficients and a compressive sensing optimum to find the coefficients for given rotation (Tsilifis et.al, 2019). A third procedure carries this last idea one step further by construing the rotation matrix **A** to be a model parameter to be statistically inferred from a training set of numerical samples (Tsilifis and Ghanem, 2018). This procedure starts with a Hierarchical prior for each of the reduced PCE coefficients (call them c) and **A**. A Gaussian likelihood is the constructed with **A** constrained to the Steifel manifold. The posterior measure conditional on **A** is then constructed from the exponential family with a minimum cross-entropy argument while the posterior conditional on c is sampled via geodesic Monte Carlo. This last procedure is very robust and can be initiated with as few numerical samples as available. The three procedures described herein for learning the adaptation scale linearly with the parametric dimension of the problem, thus permitting routine stochastic analyses with high accuracy.

Adapted SROM for Composite Manufacturing

Details of their manufacturing process have implications on the quality, performance and safety of composite structures. *Figure 2* shows a schematic of the steps involved in this process. The manufacturing process typically involves steps of draping, RTM, curing, and distortion. The performance prediction steps involve a sequence of homogenizations to account for residual stresses and micro-constituents. *Figure 3* shows typical experimental data available during and following the manufacturing process, highlighting the need for a statistical analysis of the underlying physical processes.

A detailed analysis of the manufacturing process alone would involve close to 75 input parameters, describing mechanical and geometrical properties of the fibers as well as elastic, inelastic, chemical, and thermal properties of the resin.

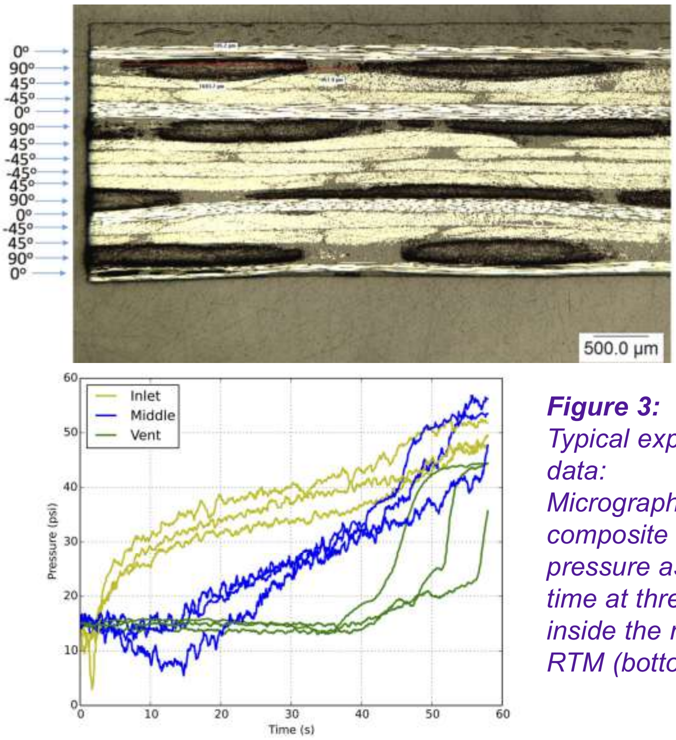


Figure 3:
Typical experimental data:
Micrograph of hardened composite (top), pressure as function of time at three locations inside the mold during RTM (bottom)

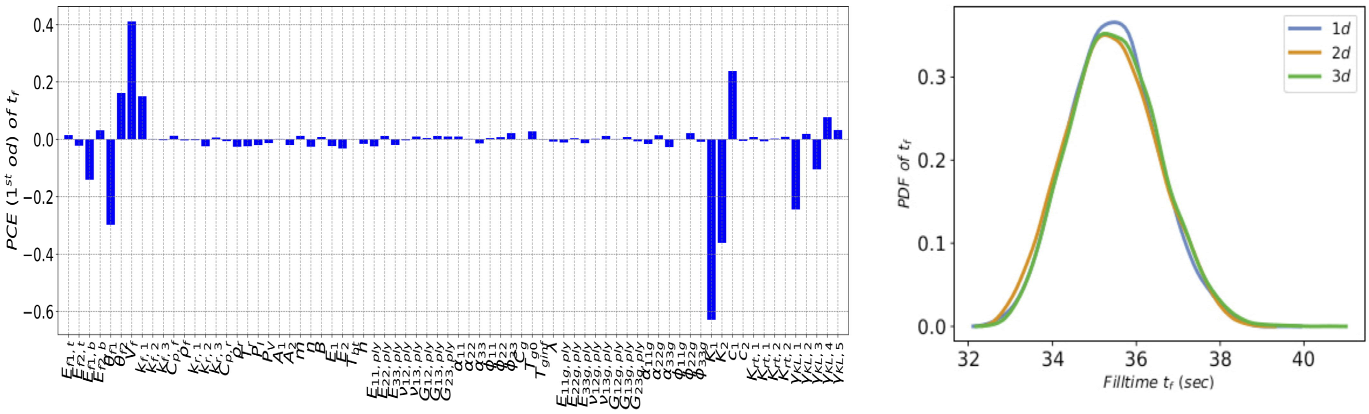


Figure 4:
Sensitivity coefficients for filltime (left) and PDF of filltime using 1d, 2d, and 3d adapted SROM; full model has 75 stochastic dimensions

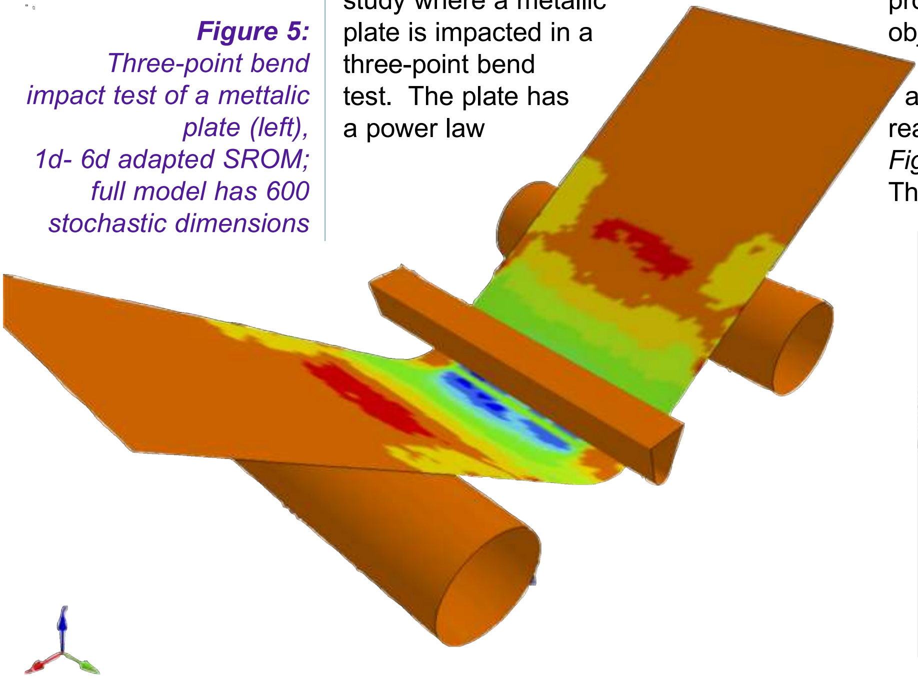
The computational burden of even a single deterministic realization can be daunting, and is exacerbated by the need to explore multiple scenarios. For design optimization purposes, however, the full-field evaluation of temperature, chemical potentials, and flow fields over the whole domain and for the duration of the manufacturing process, is not required. In this case, three quantities of interest are of most significance, mainly the filltime, the curetime, and the maximum residual stress in the domain at the conclusion of distortion. *Figure 4* shows the sensitivity coefficients (first order PCE coefficients) and probability density functions of the filltime using low-dimensional adapted SROM.

While the sensitivity coefficients clearly show that a significant number of input parameters are influential on the filltime, a 1-dimensional reduction (as seen in the right figure of *Figure 4*) is still capable of fully capturing the probability density function of the filltime. Similar results can be obtained for curetime and maximum residual stress (Ghauch et.al 2018).

Figure 5 shows results from a related study where a metallic plate is impacted in a three-point bend test. The plate has a power law hardening plasticity with each of three hardening parameters described as a spatial random field with 200 terms in its Karhunen-Loeve expansion, for a total of 600 random parameters). The analysis is carried out using LSDYNA. The QoI in the present case is the area under the load-displacement curve leading up to failure. The PDF plots shown in *Figure 5* indicate that a third-dimensional SROM is required to capture the probability density function of the absorbed energy.

Adapted SROM for Optimisation under Uncertainty

The computational burden associated with stochastic models becomes unwieldy when taken in conjunction with design optimization. This is, indeed, where basis adaptation techniques as described above, are most valuable. In this case, the QoI is identified with the objective function, and a new SROM is constructed for each set of design variables. The impact of this paradigm is demonstrated in *Figure 6* on the problem of well placement for oil depletion. The problem here is to identify the best location of an injection well and a production well in order to maximize an objective function. The subsurface has a random permeability that is described as a random field specified from a handful of realizations, with the left subfigure in *Figure 6* showing one such realization. The objective of the optimization is to



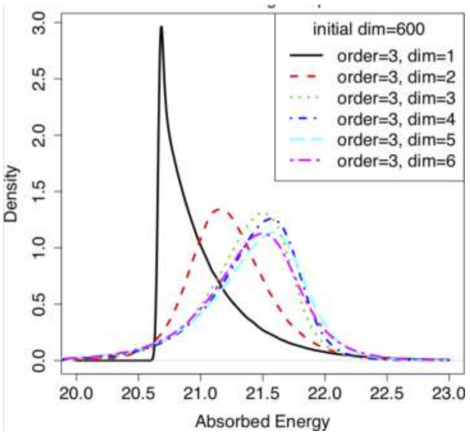


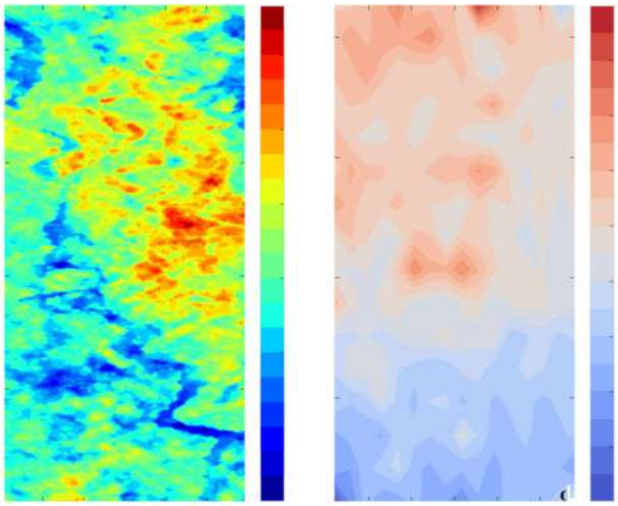
Figure 5:
Three-point bend impact test of a mettalic plate (left), 1d- 6d adapted SROM; full model has 600 stochastic dimensions

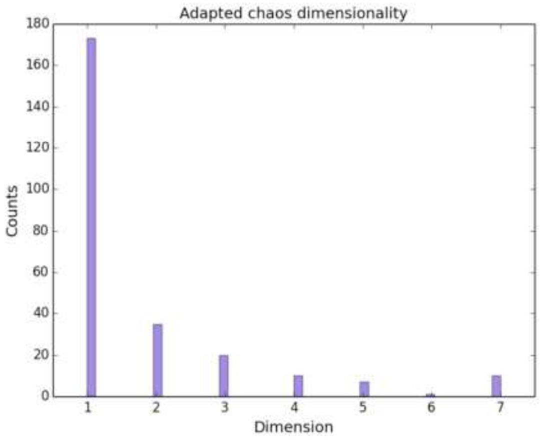
maximize the quantity of oil that can be produced with some assurance (i.e. preset probability). For each choice of injection/production wells, a random boundary value problem must be solved, following which the probability distribution of produced oil must be evaluated, and its tail explored for that value which is exceeded with the specified probability. A prohibitively large number of function evaluations would have to be carried out to credibly find the optimal well locations. By adapting the stochastic BVP to the objective function, massive reductions are achieved. The middle subfigure in *Figure 6* shows the spatial fluctuations of the rotation matrix A while the right subfigure shows the number of function evaluations associated with each stochastic dimension. It is clear that while a small number of 7-dimensional problems still needs to be evaluated, the far majority of the evaluations are for a one-dimensional SROM, which can be solved very efficiently.

Concluding Comments

The rotation matrix **A** should be construed as a new parameter for the mapping from input to QoI. There is significant leeway in specifying "how" and "what" to package into this new parameter such as constraints from physics, sparsity, and data. This is an active research area that has already lifted the curse of dimensionality, permitting the integration of advanced machine learning and UQ constructs into some of the most challenging problems in computational science and engineering. ●

Figure 6:
Optimization under uncertainty:
(left) realization of random permeability field;
(center) variation of orientation of A as function of space;
(right) number of function evaluations for each reduced dimension





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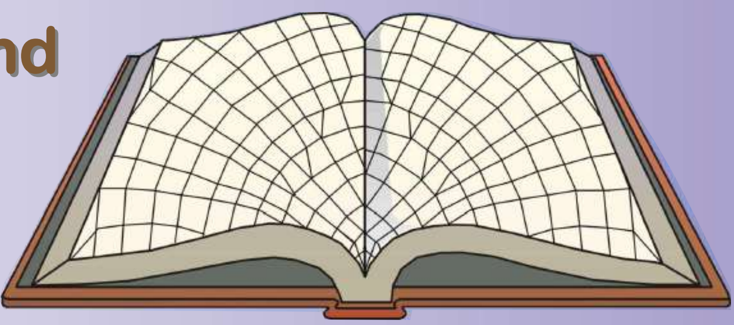
Interface Fracture and Delaminations in Composite Materials



Leslie Banks-Sills
Springer, Cham, Switzerland, 2018

BOOK REVIEW

ISBN: *978-3319603261 (eBook 978-3-319-60327-8), 120 pages, soft cover, 55 €.*

Contents: *Preface; Symbols; 1:Introduction; 2: Fundamentals of Interface Fracture Mechanics; 3: Calculation of Stress Intensity Factors – An Interface Crack; 4: Testing–Interface Crack Between Two Isotropic Materials; 5: Mathematical Treatment of Delaminations; 6: Methods of Calculating Stress Intensity Factors–Delaminations; 7: Testing–Delamination Between Two Dissimilar Plies; Appendix A: Stress and Displacement Functions for an Interface Crack between Two Isotropic Materials; Appendix B: Matrices for Different Anisotropic Material Paris; Appendix C: Stress and Displacement Functions for an Interface Crack between Two Anisotropic Materials; Index*

This short book appeared in the Springer Briefs series. The author is a professor in Tel Aviv University, and a well-known expert in combined experimental-computational fracture mechanics. On a personal note, Prof. Sills was an inspiring teacher in my BSc and MSc studies, in diverse courses such as rigid-body dynamics and fracture mechanics.

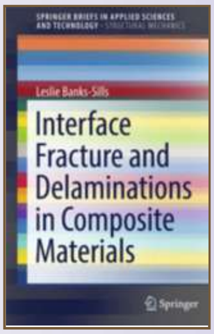
The book is concerned with interface fracture and with delaminations. The prototype problem of interface fracture is that of a crack along the interface between two bonded isotropic and homogeneous materials. The prototype problem of delamination is the separation of plies in a composite material. The latter may be regarded as the problem of an interface crack between two bonded anisotropic materials.

The preface and the back cover do not indicate the readership to whom this book is intended, but it seems to me that graduate students and practitioners interested in interface fracture and delaminations will benefit from the book if they have some background in elasticity and fracture mechanics and are familiar with the finite element (FE) method. In particular, since the fundamentals of linear fracture mechanics (for a homogeneous and isotropic material) are covered by 5 pages only of the Introduction, I believe that without basic knowledge in fracture mechanics, the reader would find it difficult to absorb the material covered in the book.

Following the Introduction, the book is divided into two parts: Part I on interface fracture and Part II on delaminations in composites. Each of these parts consists of three chapters: the first introducing the basic theory, the second discussing methods for calculating stress intensity factors (SIFs), and the third describing lab testing methods. This structure is appealing, since it emphasizes the three facets of engineering work – analytics, computation and experimentation – and implies that they should be practiced in tandem, as the author has done and promoted for many years.

Each chapter starts with an abstract and a list of keywords, and ends with an alphabetic list of references. The book contains many illustrations and is generally pleasing to the eye and well structured.

For obvious reasons, I will focus on the two chapters that deal with computational methods. These are chapters 3 and 6, discussing methods for calculating the SIFs of interface cracks and delaminations, respectively. In both cases, the crack is modeled using a quarter-point quadratic element; see *Figure 1*. The transformation from the parent element to this quarter-point element yields a singularity (the Jacobian vanishes) at the location of the crack tip, and it is a happy coincidence that this singularity is exactly the square-root singularity that the solution should possess at the crack tip. While this is the simplest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Leslie Banks-Sills
Interface Fracture and Delaminations in Composite Materials
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possible way to model a crack, it seems to work surprisingly well, and the author states that these elements "have been found to produce excellent results."

The first method for calculating the SIF is the displacement extrapolation method. The idea is to use FE analysis to find the crack opening displacement (COD) as a function of the radial distance r from the crack tip. From the COD and the asymptotic expansion of the displacements around the crack tip one can find the three "extended" SIFs as a function of r. At the crack tip itself these functions have the form 0/0, so extrapolation is used in order to find their limits as r goes to zero. In doing so, one should be careful not to use values too close to the crack tip, since they may be polluted by a round-off error.

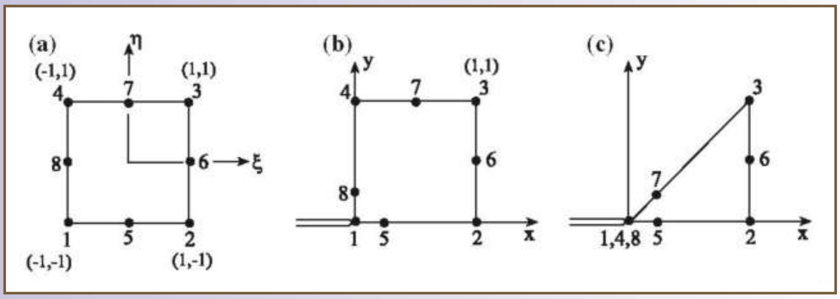


Figure 1:
The quarter-point quadratic element used for crack modeling.
This is Fig. 3.1 in the book

The second method of calculating the SIF is the one I like best: the M-integral method. The M-integral is an extension, originally developed in 1977 by Chen and Shield, of the celebrated J-integral introduced by Jim Rice. The J-integral method is limited in that it cannot provide separately the three SIFs in mixed-mode problems but only the sum of their squares. In the M-integral method one defines a path-independent integral which depends on two problems: the original one which we wish to solve and an auxiliary problem. Then three different auxiliary problems are used to produce enough equations that would give us the three SIFs for the original problem. I find this method to be ingenious and elegant, and I wonder why it is not more well-known than it is. The setup for the M-integral method in the case of an interface crack is described in *Figure 2*.

Jim Rice

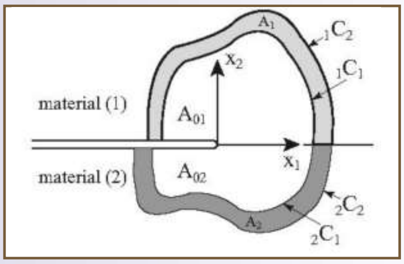


Figure 2:
Setup for the M-integral method.
This is Fig. 3.4 in the book

The third method is the virtual crack closure technique.
It requires two FE analyses: one for the original problem and another for a problem in which the crack is slightly elongated. The calculation is based on the Irwin crack closure integral. See *Figure 3* for the setup.

The three methods for calculating SIFs are described first in Chapter 3 for the case of an interface crack. Then, in Chapter 6, they are described again for the much more complicated problem of delamination between two plies in a composite material. Various configurations of composites are discussed. Two types of crack-tip singularities appear in this case: the usual square-root singularity $r^{-1/2}$, and the oscillatory square-root singularitiy $r^{i\varepsilon-1/2}$, where ε is a parameter which depends on the material properties in a complicated manner.

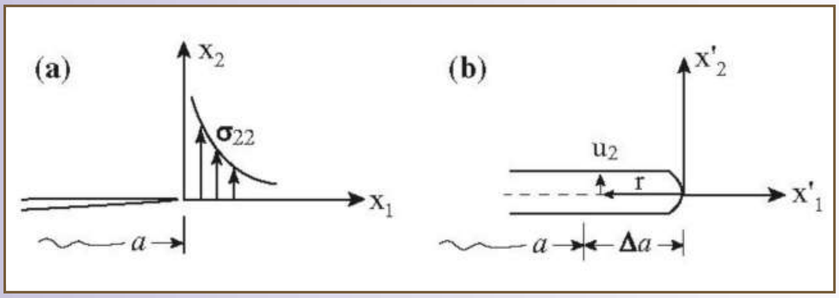


Figure 3:
Set up for the Virtual Crack Closure Technique.
This is Fig. 3.8 in the book

A slight inconvenience associated with this book is the fact that it is far from being self-contained. In various places the author directs the reader to other sources for the derivation of formulas used in the book. For example, for the derivation of the M-integral, the reader is advised to read a paper by the author's group from 1999. However, this may be unavoidable since it is hard to include the entire material in a 120-page text, as dictated by the format of the Briefs series.

In summary, this is an excellent short book providing the state of the art of combined computational and experimental methods for interface cracks and delaminations. It is highly recommended for readers with the appropriate background and interest. ●

In Memoriam

Erwin Stein

(1931 - 2018)

On December 19, 2018, Erwin Stein, my colleague and friend for 60 years, died at the age of 87 after some days of sudden unconsciousness, which had overtaken him late in the night of December 13 after working at his desk.

With Erwin Stein the community of Computational Mechanics is losing a nationally and internationally highly renowned scientist, and the German Association of Computational Mechanics one of its founders and honorary presidents.

Figure 1: *Erwin Stein (1931-2018)*

Erwin Stein was born on July 5, 1931 in Altendiez /Lahn. After his highschool finals, he studied from 1951 at the Technische Hochschule Darmstadt taking courses mainly in civil engineering but also in mathematics. After receiving his diploma in civil engineering in 1958, Erwin Stein first took a position in a consulting firm for bridge engineering.

But already in 1959, he started his scientific career by accepting an offer from Professor Bornscheuer of the Technische Hochschule Stuttgart, where he worked with great commitment for about 12 years. In this time, the computer based methods of structural mechanics came into the focus of research. With enthusiasm, Erwin followed this new field leading in 1964 to his dissertation and in 1969 to his "Habilitation" and venia legendi.

The main part of the academic career of Erwin Stein is connected to the University of Hannover, however. In the year 1971, he accepted a call to the chair of "Baumechanik" at the Department of Civil Engineering of the Technische Universität Hannover.
He remained there until his retirement in 1998 and even beyond as Emeritus another 20 years, in which he worked as hard as before.

In this long period, Erwin Stein formed an institute of high national and international reputation. With his team, he achieved substantial progress in the field of Computational Mechanics, especially in computational structural and solid mechanics and became well-known for the profound quality of his research.
He worked in wide-spread research areas, from basic theoretical formulations to numerical realization and practical applications. On the one hand, he accentuated practical problems of analysis and design, the latter influenced by his license as Proof-Engineer (Prüfingenieur) which he obtained in 1975. He also emphasized the importance of mathematics and enforced the collaboration of engineers with applied mathematicians. The broad spectrum and the development of his research is reflected in his numerous papers (more than 300) in highly ranked journals, books, and conference contributions. He was editor or coeditor of many books, journals, and proceedings, including the Encyclopedia of Computational Mechanics. With his team he initiated and worked on numerous research projects.

In his teaching responsibilities Erwin successfully educated in his profound manner students of civil engineering for 27 years in the basics of mechanics as well as in advanced courses. Quoting himself from one of his papers: " Structural engineers need ingenium - this Latin word means imagination, rational thinking, talents for theoria cum praxi, (natural) determination ... -" gives some of the motivation about his teaching approach. Sometimes even some philosophical notes were added to the often demanding contents of his lectures.

With his enthusiasm he managed to attract the top students to his institute and formed a highly qualified team of scientists, the so-called "Stein-School". Many of his coworkers became professors at various universities expanding his ideas, and their institutes in turn developing to recognized centers of excellent research in many areas of computational mechanics.

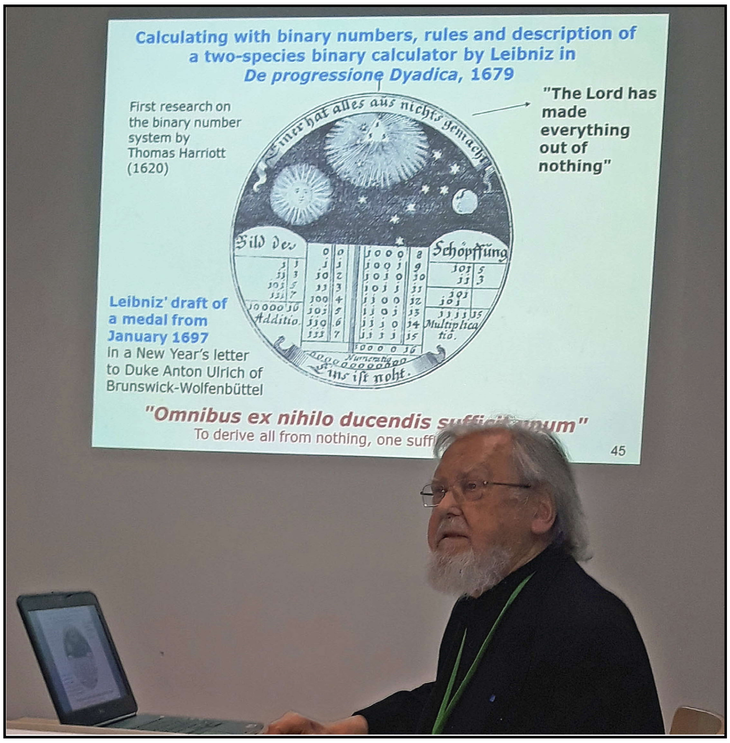
Erwin Stein established and maintained a worldwide network. He was one of the founders of the International Association of Computational Mechanics (IACM) as well as of the German Association of Computational Mechanics (GACM). With his dedicated commitment he contributed essentially to the development of these and related organizations. He was a regular participant in national and international congresses, often giving invited or plenary lectures, always on a sophisticated level.

As an exceptional contribution to the scientific community, his research about Gottfried Wilhelm Leibniz has to be emphasized. In the time of his retirement Erwin became more and more attracted by the person and the work of this last universal scholar. He even tried hard to read some of his contributions in the original Latin language. In particular, he improved Leibniz' four species calculating machine (machina arithmetica 1698) by a new construction built together with a mechanical engineer. With this and other rebuilt machines of Leibniz, he formed an exhibition at the University of Hannover, which was also shown at several other universities and places. Several publications describe his impressive research work, especially his last book: "Der Universalgelehrte Gottfried Wilhelm Leibniz" - edited together with A. von. Boetticher - includes several chapters of the recent Leibniz-research of Erwin. On many occasions he praised the work and ideas of this great scientist, as in his last lecture given at the GAMM Annual Meeting in Munich in March 2018. (*Figure 2*). In 2011, he was awarded the "Verdienstkreuz 1. Klasse des Niedersächsischen Verdienstordens", in appreciation of special efforts in science and research and his accomplishments for the inheritance of Leibniz.

In recognition of his academic merits, Erwin Stein also received four honorary doctorate degrees and other awards, among them, the Gauß-Newton Medal of the International Association for Computational Mechanics (IACM) and the Ritz-Galerkin Medal of the European Community on Computational Methods in Applied Sciences (ECCOMAS). He was honorary member of several scientific organizations and honorary president of the GACM.

The community of Computational Mechanics is grateful for his achievements and impulses and will cherish his scientific legacy. Erwin Stein was an exceptional scientist and a great personality.
We mourn his loss and express our sorrow and sympathy to his wife Gisela und his children.
His presence will be missed but our memories of him and of his friendship will remain. ●

Walter Wunderlich
(Honorary President of GACM)



Calculating with binary numbers, rules and description of a two-species binary calculator by Leibniz in *De progressione Dyadica, 1679*

First research on the binary number system by Thomas Harriott (1620)

"The Lord has made everything out of nothing"

Leibniz' draft of a medal from January 1697
In a New Year's letter to Duke Anton Ulrich of Brunswick-Wolfenbüttel

"Omnibus ex nihilo ducendis s[illegible]num"
To derive all from nothing, one suffi

Figure 2:
At the GAMM-Meeting in Munich 2018

Korean Congress on Computational Mechanics

February 14 - 15, 2019

1st Korean Congress on Computational Mechanics 2019 was held in the Hanyang Unviersity Chung Mong-Koo Automotive Research Center, Seoul, Korea, on 14~15 Feb 2019. The workshop organized by Korean Society for Computational Mechanics aims to bring together Korean researchers in the field of computational mechanics and encourage research exchange and networking.

Figure 1:
Group Photo of KCCM 2019 Attendants and Presidents

KSCM 2018 Winter Workshop

November 20, 2018

KSCM 2018 Winter Workshop was held in the Four Seasons Hotel Seoul, Korea, on 30 November 2018. The workshop, organized by Korean Society for Computational Mechanics, aims to bring together Korean researchers in the field of computational mechanics and encourage research exchange and networking.

Figure 3:
Group Photo of KSCM 2018 Winter Workshop Attendants and Speaker:
Eunjung Lee (Yonsei University)

for all inclusions under ***KSCM***
please contact
Dongchoul Kim
김동철 dckim@sogang.ac.kr

This is the first national conference co-hosted by COSEIK (Computational Structural Engineering Institute of Korea), KSAS (Korean Society for Aeronautical & Space Science) Structure and Aerodynamics division, KSCE (Korean Society of Civil Engineers) Computational Mechanics division, KSIAM (Korean Society for Industrial and Applied Mathematics), and KSME (Korean Society of Mechanical Engineers) CAE & Applied Mechanics division.
Further information will be found at: **http://www.kscm-society.org/**. ●

Figure 2:
Keynote Speakers of KCCM 2019: Eun-Jae Park (Yonsei University) and Heoung-Jae Chun (Yonsei University)

Three speakers – *Eunjung Lee* (Yonsei University), *Yongdae Shin* (Seoul National University), *Hansohl Cho* (KAIST) – gave lectures on recent research trend in computational mechanics.
Further information will be found at: **http://www.kscm-society.org/..** ●

Figure 4:
Speakers of KSCM 2018 Winter Workshop:
Attendants and Speaker : Yongdae Shin (Seoul National University)
and Hansohl Cho (KAIST)

The Japan Society for Computational Engineering and Science

- The JSCES General Assembly Meeting and Special Symposium -

Figure 1:
General assembly meeting

Figure 2:
Prof. Yoichi Sumi at the JSCES special symposium

The 2019 general assembly meeting of JSCES was held at the Ito International Research Center, the University of Tokyo, Japan, on May 23, 2019. Both the operating and financial review for the previous fiscal year and operation and financial plan for this fiscal year were reported in this meeting *(Figure 1)*. The general assembly meeting was followed by the JSCES special symposium, in which a lecture was given by Dr. Yoichi Sumi, the Professor Emeritus of Yokohama National University. He delivered a talk entitled “Theories of Pattern-Formation in Crack Propagation and Fracture Control” *(Figure 2)*. He explained about the pattern formation and the evolution of crack propagation in engineering materials and structures, bridging mathematical analyses of cracks based on singular integral equations, to computational simulation of engineering design. Several design concepts are discussed for the prevention of fatigue and fracture in engineering structures, such as hull structures of ships. Prof. Yoichi Sumi also introduced the numerical simulation method of a system of multiple cracks by means of the finite element method, which may be used for the better implementation of fracture control in engineering structures. ●

Award Ceremony for JSCES Prizes

On the same day, JSCES prizes were presented to those researchers and practitioners who have marked outstanding achievements and contributions.

Figure 3:
Back Row: Dr. A. Sekine, Mr. T. Sasagawa, Dr. M. Tanaka, Mr. S. Matsushita, Mr. T. Shono, Prof. S. Matsubara, Mr. T. Terajima
Front Row: Dr. Y. Yoshida, Prof. M. Tsubokura, Dr. M. Tateishi, President T. Yamada, Dr. M. Shoji, Mr. S. Fujikawa, Prof. H. Takizawa

This year’s recipients were: Dr. Yuichiro Yoshida (The JSCES Achievements Award), Prof. Makoto Tsubokura (Kawai Medal), Mr. Satoshi Fujikawa (Shoji Medal), Prof. Hideo Takizawa (Technology Prize) and Mr. Takashi Terajima (Technology Prize). Paper awards associated with the Transaction of the JSCES (see, https://www.jstage.jst.go.jp/browse/jsces) were also given to the following researchers: Dr. Masato Tanaka, Mr. Takashi Sasagawa, Dr. Ryuji Omote and Dr. Fumio Fujii (Outstanding Paper Award), Mr. Shintaro Matsushita and Prof. Takayuki Aoki (Outstanding Paper Award), Dr. Akihiro Sekine (Young Researcher Paper Award) and Mr. Tatsuhiro Shono (Young Researcher Paper Award). Moreover, Prof. Shigeru Obayashi and Dr. Motoharu Tateishi were awarded as fellow members, and Dr. Seishiro Matsubara was awarded for his outstanding Ph.D. dissertation *(Figure 3).* ●

The JSCES Grand Prize 2018

On the second day of the conference, a plenary lecture entitled “Practical Multiscale Framework” was delivered by Dr. Jacob Fish, the Carleton Chaired Professor of Columbia University, USA *(Figure 7)*. In his lecture, he presented a practical multiscale framework, which possesses such salient features as computational efficiency, absence of the usual scale separation assumption, and reliance only on limited experimental data for its calibration.

He explained about the multiscale software developed based on this framework, known as the Multiscale Designer, which has been deployed by hundreds of

Annual Conference

The 24th JSCES's Annual Conference on Computational Engineering and Science, chaired by Prof. T. Nagashima (Sophia Univ.), was held during May 29–31, 2019, at Sonic City hall (Omiya, Japan). The conference was attended by about 540 participants, and about 320 papers with full lectures were presented by researchers, graduate students and practitioners.

Fruitful discussions were exchanged in 29 organized sessions associated with a plenary lecture, graphic awards and six 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 five, young professors and researchers *(Figure 4)*. The participants were informed on the images and excitements of career paths after their graduation.

Figure 4:
A special seminar for students

The JSCES scholarship awards, also aimed to promote young researchers, were presented to Mr. Yuya Yamaguchi (Tohoku Univ.) and Dr. Takafumi Sasaki (Waseda Univ.) *(Figure 5)*. The banquet of the conference was held at the Railway Museum, a very unique atmosphere with historic trains in the surroundings *(Figure 6)*.

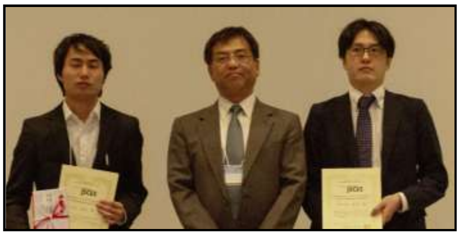


Figure 5:
Mr. Yuya Yamaguchi (left) and Dr. Takafumi Sasaki (right) with President T. Yamada

Figure 6:
A group shot in the Railway Museum

Figure 7:
Prof. Jacob Fish at his special lecture

Figure 8:
Prof. Jacob Fish receiving the JSCES Grand Prize 2018

industrial users around the globe for durability, life prediction and environmental degradation of ceramic- and polymer- based composite components, automotive industry for crash prediction of composite cars, electronics industry, and other industries, such as healthcare, consumer goods, and civil engineering.

Prof. Jacob Fish received "The JSCES Grand Prize 2018", for his outstanding contributions in the field of computational engineering and sciences, at the following ceremony *(Figure 8)*. ●

JACM 日本計算力学連合

Japan Association for Computational Mechanics

The JACM is a loosely coupled umbrella organization covering 29 computational mechanics related academic/industrial societies in Japan through communication with e-mail and web page (https://ja-cm.org/index-j.html). The number of individual members is about 330. In the election for the president, the general council members representing the participating societies voted.

Figure 1: *Professor Shinobu Yosjhimura, delivering the opening remarks*

JACM took a part of the Eighth Computational Mechanics Symposium held on December 12, 2018. 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). The annual SCJ Computational Mechanics Symposium has become a new tradition and is an evidence of how Japanese science and engineering community finds computational mechanics to be a very important area.

Figure 2: *Mr. Tohru Hirano, During the panel discussion on “Society 5.0”*

In the eighth symposium, Professor Seiichi Koshizuka of University of Tokyo served as the general chair. After the opening remark by Professor Shinobu Yoshimura of University of Tokyo, eight young researchers representing the participating computational mechanics related societies presented their latest research outcomes. Majority of them were the recent award recipients of the participating societies. JACM was represented by Professor Tinh Q. Bui of Tokyo Institute of Technology. Professor Bui presented “Stochastic High-Performance Computing for Modeling Spot-Welds Failure”. The talk covered not only fundamental investigation but also the outcomes of his industrial collaborations. Professor Tinh Q. Bui was the recipient of the 2018 JACM Young Investigator Award. The speakers are as listed below in the order of their presentations. Each speaker was introduced by the president, vice president or the head of the division of his/her representing society.

- ***Professor Youhei Takagi*** of Yokohama National University, “CAE Konwakai”
- ***Professor Hiro Tanaka*** of Osaka University, “The Computational Mechanics Division of The Japan Society of Mechanical Engineers (CMD, JSME)”
- ***Dr. Daisuke Nishiura*** of Japan Agency for Marine-Earth Science & Technology (JAMSTEC), “Japan Society for Computational Engineering & Science (JSCES)”
- ***Professor Tinh Q. Bui*** of Tokyo Institute of Technology, “Japan Association for Computational Mechanics (JACM)”
- ***Professor Tomonori Yamada*** of University of Tokyo, “The Japan Society for Simulation Technology (JSST)”
- ***Professor Yuriko Takeshima*** of Tokyo University of Technology, “The Visualization Society of Japan (VSJ)”
- ***Dr. Yusuke Imoto*** of Tohoku University, “The Japan Society for Industrial and Applied Mathematics (JSIAM)”
- ***Professor Hiroshi Isakari*** of Nagoya University, “Japan Society for Computational Methods in Engineering (JASCOME)”

Following the presentations of the young researchers, a panel discussion entitled “Establishment of Computational Information Science Foundation for Human, Artifact Systems and Services supporting Society 5.0” was held.

The moderator, Mr. Tohru Hirano (*Figure 2*) of Daikin Information Systems Co. Ltd, explained the key concept of Society5.0, which was formulated by Japanese government aiming toward a human-centered society (*Figure 3*). Society 5.0 is based upon Cyber Physical System as the key architecture with AI assisted value-added smart services, and balances the economic development with the resolution of the social issues such as declining population and aging society. For the realization of Society 5.0, real world modeling methodologies (Digital Twin) including human and society as the system models were presented. Then, as the academic background for realizing Society 5.0, the foundation of "Computational Information Science", which is the integration of Computational Science, Design Science, Information Science and Behavioral Economics, was proposed (*Figure 4*).

The first panelist, Dr. Masahiro Murakawa of National Institute of Advanced Industrial Science and Technology (AIST), presented "Diagnostic Support for Infrastructure by Data-driven Anomaly Detection Technology". He explained quite impressive Machine Learning application for detecting anomaly condition of real wind generation systems installed in different places in Japan. He employed Transfer Learning technology to improve drastically the learning efficiency with separate learning processes for feature extractor and classifier with many different system's operational data.

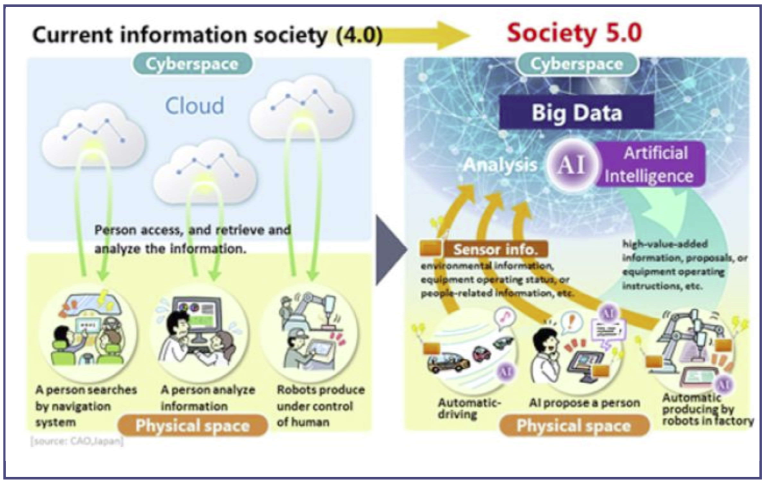


Figure 3:
The concept of Society 5.0 (Courtesy of Cabinet Office, Government of Japan)

The second panelist, Professor Takanori Ida of Kyoto University, Faculty of Economics, presented "Energy Management System Viewed from Behavioral Economics". He explained on Bounded Rationality of human in the real social systems and presented several real case studies of Energy Management System implementations in different cities in Japan. From his various in experiences of Field Economics, he insisted on employing several concepts of Behavioral Economics, such as Bounded Rationality, Bias and Nudge, for the real social implementation.

The third panelist, Professor Hiroshi Okuda of University of Tokyo, Graduate School of Frontier Sciences, presented "Digital Value-added Simulation". He explained two different social simulation technologies, macroscopic regression model and microscopic Multi-Agent Simulation, for the evaluation of new artifact's social acceptance, and concluded that Multi-Agent Simulation is the effective approach to understand the real world consisting of consumers who interact with each other in complex ways with diverse values and behavior norms. He also presented the original development of Multi-Agent Diffusion Simulation framework (MADS).

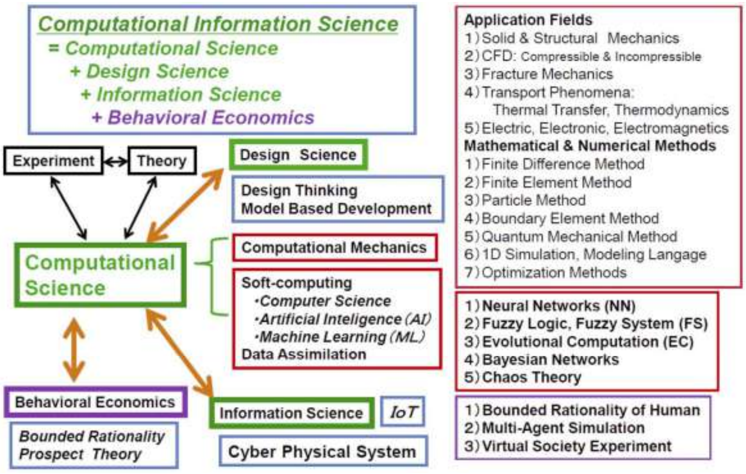


Figure 4:
The Foundation of "Computational Information Science" to realize Society 5.0

Then, the moderator and the panelists had discussed to establish Scientific Foundation for the Human, Artifact Systems and Smart Services, and had deep consensus on the necessity of the academic background for the realization of Society 5.0.

The symposium was closed with the closing remarks by Professor Ichiro Hagiwara of Meiji University. (It is noted that the part of this report on "Society 5.0 panel discussion" was provided by Mr. Tohru Hirano.) ●

Figures 5:
Speakers and participants of the 8h Computational Mechanics Symposium

UK acm
UK Association for Computational Mechanics

for all inclusions under ***UKACM*** *please contact*
Rubén Sevilla
r.sevilla@swansea.ac.uk

Welcome from the new UKACM President

Figure 1:
Dr Rubén Sevilla

The Association of Computational Mechanics in Engineering in the United Kingdom (ACME-UK) was founded in March 1992 to promote research in Computational Mechanics in the UK and to establish formal links with similar organisations in Europe and the rest of the world. The association changed its name in 2016 to be the UK Association for Computational Mechanics (UKACM). Olgierd C Zienkiewicz (18 May 1921 – 2 January 2009) from Swansea University, was instrumental in setting up the Association in 1992 and it is both a great privilege and an honour for me to serve UKACM as the second president from Swansea.

I am thankful to the previous president, Charles Augarde, who has done an excellent job for the Association during the last three years. I am also grateful to the team of UKACM officers Omar Laghrouche (Treasurer), Tony Jefferson (Secretary) and Marco Discaciati (Webmaster).

I am eager to continue supporting the younger generation of UK researchers. Our aim is to ensure that the UKACM helps them to achieve their goals. After attending the last ECCOMAS conference in Glasgow and the last UKACM conference in London, I am pleased to see the quality of the work done by our younger generation of researchers and I am proud to see that the main event of UKACM, our national conference, keeps its focus on them. It is clear that UKACM faces extra challenges in the next years due to the uncertainty of Brexit. We will certainly work to ensure that our links with ECCOMAS are just as strong, if not stronger.

26th Conference of the UK Association for Computational Mechanics

The 26th Conference of the UK Association for Computational Mechanics took place from the 10th to 12th of April in City, University of London. The conference was organised by Prof. Roger Crouch, Dean of the School of Mathematics, Computer Science and Engineering. The history of City University goes back to 1852, when the Northampton Institute was founded. City received the Royal Charter in 1966 becoming The City University.

As usual, the conference placed particular emphasis in researchers who are at an early stage in their career (i.e. doctoral students and post-doctoral researchers). The team at City devised a novel conference format where researchers were encouraged to present their work following the style of the one of the most gifted and much-admired UKACM presenters, the late great Mike Crisfield. The photograph shows one of the delegates delivering one of these presentations.

Figure 2:
A delegate delivering his presentation at the 26th Conference of the UKACM

More than 65 papers were presented this year, with topics ranging from fundamental numerical developments to advanced engineering applications in a variety of fields including solid mechanics, fluid dynamics and wave propagation.

In London, we were testimony of the high quality of the work undertaken doctoral students and post-doctoral researchers in the UK and I certainly anticipate a bright future for this generation. Professor Crouch also treated the delegates by organising the conference dinner in the beautiful Goldsmiths' Hall. ●

Jason Reese

It is with great sadness that I, on behalf of UKACM, inform you that Jason Reese passed away on Friday 8th March 2019. Professor Reese was a recognised world authority in the field of computational multi-scale fluid dynamics. After graduating from Imperial College London, Professor Reese completed an MSc and DPhil in the University of Oxford. Following research positions in Berlin and Cambridge, he became a lecturer in Aberdeen and King´s College. In 2003 he was appointed Professor at Strathclyde University and since 2013 he was Regius Chair in Edinburgh University. He was Fellow of the Royal Academy of Engineering and the Royal Society of Edinburgh and contributed greatly to the activities of the European Community of Computational Methods in Applied Sciences (ECCOMAS) where he represented the UK in the computational fluid dynamics committee and recently co-chaired the ECCC-ECFD 2018 Conference in Glasgow. Professor Reese will be greatly missed and our hearts go out to his wife and daughter, Alex and Zoe, in this time of sorrow.

14th WCCM & Eccomas Congress 2020

Paris, 19-24 July 2020

The joint 14th World Congress on Computational Mechanics and 8th European Congress on Computational Methods in Applied Sciences and Engineering will be held in Paris, 19-24 July 2020. The congress will take place at the “Palais des Congrès”, situated in Paris 17th district, Porte Maillot, a stone’s throw from the Champs-Elysées.

Conference organizers:

Computational Structural Mechanics Association (CSMA)

French Mechanical Association (AFM)

French Association of Applied and Industrial Mathematics (SMAI)

Group for Numerical Methods in Engineering (GAMNI)

German Association for Computational Mechanics (GACM)

International Association of Applied Methematics and Mechanics

Minisymposia:

Relevant scientists in the fields of the congress are invited to propose and organize Minisymposia. Participation of research teams from all parts of the world is welcomed and encouraged, as well as proposals of Minisymposia in new developing areas.

Guidelines for the proposal and organization of Minisymposia and detailed information concerning the congress are available at the conference website **www.wccm-eccomas2020.org**

Young researchers activities:

As expected by the organization team, the Congress programme will promote activities from and for junior researchers.

On the one hand, and outside of the traditional ECCOMAS PhD Olympiad, the ECCOMAS Young Investigator committee will carry on proposing sessions that have been very successful during previous events. Among them, we can list a Young Investigators Minisymposium with specific format (such as presentation in pairs), a Science Slam as an evening funny event, or an Academic Career Lunch.

On the other hand, other innovative activities dedicated to young researchers will be launched during the congress. As an example, the first Computational Engineering Career Fair will be organized in association with representatives of several national and international companies. Free pre-conference courses organized by the young community are also envisionned, as well as a social event oriented towards the visit of Paris. ●

CSMA Prizes

Every year CSMA rewards the best two PhD thesis of the year. For the 2018 edition, the CSMA prize committee has examined 25 applications. The two awardees are **Enora DENIMAL** and **Brian STABER**. Brian STABER is designated as the CSMA candidate for the ECCOMAS award for the best PhD theses in 2018.

Enora DENIMAL

Prediction of friction instabilities by meta-modeling and frequency approaches- Applications automotive break squeal

Advisor:
Jean-Jacques Sinou
(École Centrale de Lyon)

Brake squeal is a noise nuisance that represents significant costs for the automotive industry. It originates from complex phenomena at the frictional interface between the brake pads and the disc. To build a robust brake system, it is necessary to limit instabilities despite some uncertain parameters present in the system. Thus, one of the main objectives of the PhD thesis is to develop a method to treat and propagate the uncertainty and variability of some parameters in the finite element brake model with reasonable numerical costs.

First, the influence of a first group of parameters corresponding to contacts within the system was studied in order to better understand the physical phenomena involved and their impacts on the squealing phenomenon. An approach based genetic algorithms has been implemented to identify the most unfavorable set of parameters in terms of squeal propensity on the brake system.

> *“ demonstrating its feasibility on the complete industrial brake finite element model.. ”*

In a second step, different meta-modelling methods were proposed to predict the stability of the brake system with respect to different parameters (design parameters or uncertain parameters) related to the environment of the brake system.

In a third step, a non-linear analysis method was proposed and developed. It is based on the tracking of the stability of an approximate vibrational solution and allows the identification of unstable modes present in the dynamic response of the system. This method was applied to a simple academic model before demonstrating its feasibility on the complete industrial brake finite element model under study.

Current situation:
Enora Denimal is currently research associate at Imperial College, London, UK. ●

> *" show that the presented methodology allows for the integration of multiscale-informed surrogates with improved stability.. "*

Brian STABER:

Stochastic analysis, simulation and identification of hyperelastic constitutive equations

Advisor:
J. Guilleminot
(Duke University/Université Paris-Est Marne-la-Vallée)

This thesis is concerned with the construction, identification and simulation of stochastic nonlinear constitutive laws for nonlinear materials. The class of hyperelastic models is considered with the aim of addressing a wide range of applications from engineered polymeric composites to soft biological tissues.

The main objective, in the first part of this research, is to provide an integrated modeling approach for selected classes of stored energy functions, including incompressible and compressible media, isotropic and anisotropic materials, and homogeneous and spatially-dependent nonlinear behaviors. The methodology relies on an information-theoretic formulation, which enables the integration of mathematical constraints related to the existence and uniqueness of stochastic solutions. An efficient sampling algorithm is specifically devised to address uncertainty quantification on non-regular domains. Applications to various soft biological tissues such as arterial walls, brain tissues, spinal cord white matter, and liver tissues are provided. In the second part of the work, multi-scale analysis is investigated through the construction of surrogate models for computational nonlinear homogenization. Classical polynomial approximations are considered and subsequently used to define approximations of effective potentials within appropriate classes of stored energy functions. Numerical benchmarks are conducted on nonlinear microstructures exhibiting very different levels of anisotropy and mechanical contrast, and show that the presented methodology allows for the integration of multiscale-informed surrogates with improved stability in FE2-type approaches.

Current situation:
Brian Staber is currently post-doc at Safran-Tech and Centre des Matériaux laboratory (UMR CNRS 7633), France

CSMA selected the PhD thesis of Brian STABER for the ECCOMAS Olympiads 2019 ●

Thematic Conference:

Uncertainty Quantification in Computational Solid and Structure Materials Modeling

The USACM Thematic Conference on Uncertainty Quantification in Computational Solid and Structural Materials Modeling, was held January 17-18, 2019 on the campus of Johns Hopkins University in Baltimore, Maryland and sponsored by the USACM UQ Technical Thrust Area. There were 26 invited speakers, and a total of 79 participants. Twenty posters were presented by graduate student and postdoctoral attendees.

The performance of structural materials is strongly influenced by uncertainties associated with composition, constituent properties, and defects. This is especially true as materials approach failure and undergo large inelastic deformations, fracture, and fatigue. Computational modeling of these materials is further complicated by uncertainties in material model-form (e.g. incomplete physics), lack of data to quantify material structure and/or property distributions, and computational cost of uncertainty analyses among other challenges.

The aim of the 2-day thematic workshop was to bring together prominent scholars in solid and structural mechanics, materials science, and applied mathematics with a shared interest in uncertainty quantification and computational material modeling to exhibit the state-of-the-art, collectively identify existing and future challenges, and promote promising new ideas in the field. The workshop focused on understanding and quantifying uncertainties in material structure and behavior and propagating these uncertainties through computational material models. This theme encapsulated uncertainty in material performance at and across all length-scales – from atomistic to structural scale – with interest in performance across diverse structural materials ranging from concrete to metals, composites, and many others. Emphasis was placed on bringing together experts in UQ with experts in mechanics/materials who recognize the need for UQ and the challenges associated with its implementation.

Figure 1: Participants of the Conference

USACM Upcoming Events

further details at usacm.org

- ***15th U.S. National Congress for Computational Mechanics***
  July 28-August 1, 2019, Austin, Texas, USA, **http://15.usnccm.org**
- ***Recent Advances in the Modeling and Simulation of the Mechanics of Nanoscale Materials***
  August 21-23, 2019, Philadelphia, PA, USA**, http://nanomaterials2019.usacm.org**
- ***Isogeometric Analysis 2020 (IGA2020)***
  October 19-21, 2020. Banff, Canada. Email **ruth@usacm.org** for more information; website coming soon.
- ***Experimental Fracture Mechanics Meets Phase Field and Peridynamics***
  February 26-28, 2020, Baton Rouge, LA, USA. Send email to ruth@usacm.org for more information. ●

The talks focused on the following topics:

- Stochastic simulation of heterogeneous material structures including generation of tensor random fields satisfying physical constraints and multi-scale consistency
- Data-driven (Bayesian / machine learning) approaches to quantifying uncertainty in material structure/performance, physics-informed machine learning methods, model order reduction, optimal experiment design
- Mathematical challenges of bridging length-scales caused by inter-scale discrepancy in multi-scale modeling and lack of scale separation
- Uncertainties in material (constitutive) model form and model validation under epistemic uncertainty, Bayesian calibration and model discrepancy
- Efficient methods for propagation of uncertainty in material systems, including very large dimensional uncertainty at voxel-level
- Influence of random imperfections on material performance and failure, especially for additively manufactured materials, quasi-brittle materials, and biomimetic materials
- Influence of uncertainty in boundary conditions and loading
- Computational homogenization – particularly for nonlinear inelastic material behavior
- Novel statistical and numerical methods for solving stochastic materials problems
- Mechanics and materials science applications where uncertainties are important

The speakers at the workshop were Johann Guilleminot, Martin Ostoja-Starzewski, Michael Ortiz, Jia-Liang Le, Yongming Liu, Jie Li, Mircea Grigoriu, Charbel Farhat, Youssef Marzouk, Clayton Webster, George Karniadakis, Zdenek Bazant, Simon Phillpot, Wilkins Aquino, Jim Stewart, Stephen Foiles, James Kermode, Timothy Germann, Wei Chen, Jaroslaw Knap, David McDowell, Pedro Ponte-Castaneda, Sankaran Mahadevan, John McFarland, and Stephanie Termaath.
Further details and available slides can be found on the workshop webpage - **https://uq-materials2019.usacm.org/**. ●

Thematic Conference:
Topology Optimization Roundtable

The USACM Thematic Conference, Topology Optimization Roundtable, was held March 10-13, 2019 in Albuquerque, New Mexico. The event was co-organized by Prof. Glaucio H. Paulino of Georgia Institute of Technology and Miguel A. Aguiló of Sandia National Laboratories. Around 80 scientists, engineers, researchers, and students from industry, national labs, and academia took part in lively discussions related to the latest developments in topology optimization and its connection to additive manufacturing.

The lectures began with representatives from industry who demonstrated the current state of the art in commercial software packages and emphasized the research needs to move the field forward for practical applications. Research presentations followed, which included density, level-set, and phase-field methods for topology optimization with various focuses: multi-physics applications, stress-constrained problems, multi-scale design, support structure design, additive manufacturing constraints, large-scale problems, fracture resistance, machine learning, among others. In addition to the 31 lectures, the event featured a poster session, a PLATO training course led by developers from Sandia National Laboratories, and a challenge problem that highlighted the capabilities of the participants.

The participants also enjoyed a conference dinner at the National Museum of Nuclear Science and History nearby where they had an opportunity to explore the exhibits and have further discussions. ●

Figure 2:
Conference dinner at the museum

Renewal of SEMNI Executive Board

After the elections held last autumn 2018, a new executive board has been formed. The new members are Professors Javier Montáns (Polytechnic University of Madrid), Juan J. Ródenas (Polytechnic University of Valencia) and Chengxiang -Rena - Yu (University of Castilla-La Mancha). Other members have been re-elected, such as Professors Pedro Díez, Riccardo Rossi (both from the Polytechnic University of Catalonia) and Elías Cueto (University of Zaragoza, who continues serving as president). Only one half of the members of the board was subject to renewal, so the rest of the members will continue until the end of their term. They are Professors Irene Arias (secretary general), Joan Baiges, Fermín Navarrina, Antonio Huerta, and Ignacio Romero.
As past-presidents, Professors Eugenio Oñate, Manuel Casteleiro and Xavier Oliver will also continue serving in the board.

The President, prof. Elías Cueto, gratefully acknowledged the work of the members that now leave the board: Pilar Ariza, who served in the board from 2011, and Miguel Cervera and José María Goicolea, who were members after their election in 1996. ●

SEMNI and APMTAC
meet this July for their biannual conference

The Spanish and Portuguese associations, SEMNI and APMTAC, will celebrate this July their biannual conference in Guimarães, Portugal. The Congress on Numerical Methods in Engineering (CMN 2019) aims to be a forum for the discussion of relevant scientific, and technological developments in computational mechanics, numerical methods and engineering applications. CMN 2019 is jointly organized by the Portuguese (APMTAC) and the Spanish (SEMNI) Associations and follows the previous congress editions of Madrid (2002), Lisbon (2004), Granada (2005), Porto (2007), Barcelona (2009), Coimbra (2011), Bilbao (2013), Lisbon (2015) and Valencia (2017).

The scientific program will comprise plenary lectures from leading researchers and will be structured in thematic sessions in different research fields. The congress is open to professionals, researchers, educators, students and everyone else interested in numerical methods. The objective is to make the congress the best forum for dissemination of the latest scientific and technical developments and for exchange of new ideas in emerging topics.

Information, along with the program is available at http://www.cmn2019.pt. ●

SEMNI awards
2019

SEMNI has awarded its annual prizes during its last meeting of the executive board, held in Barcelona the last March 29th, 2019. The awardees will receive their prizes during the gala dinner ceremony of the joint Spanish-Portuguese Conference on Numerical Methods, CMN, to be held in Guimarães, Portugal the next July 1-3rd, 2019.

The list of awardees is the following:

SEMNI award to the best Ph.D. thesis in the field of numerical methods:
The committee, formed by profs. I. Romero (president), M. Arroyo, S. Badía, L. Cueto-Felgueroso and E. Reina, granted the prize to:

- **Dr. Aranu Pont**, for the thesis "Numerical Simulation of Aeroacoustics using the Variational Multiscale Method. Application to the problem of human phonation" advised by Ramon Codina and Joan Baiges (Universitat Politècnica de Catalunya). This thesis has represented SEMNI for the ECCOMAS award 2019.

- **Dr. Miguel Herráez** (ex aequo), for the thesis "Computational Micromechanics Models for Damage and Fracture of Fiber-Reinforced Polymers" advised by Carlos González and Claudio Lopes (Universidad Politécnica de Madrid).

Juan C. Simó award 2019:
SEMNI's prize to young researchers commemorates the legacy of the late prof. Juan C. Simó in the field of numerical methods. The committee was formed in this occasion by profs. P. Díez (president), M. Doblaré, S. Idelsohn, D. Peric and J. P. Moitinho de Almeida. In this occasion, the awardee is:

- **Prof. José Reinoso**, from the University of Seville. The committee highlighted his contributions to the field of non-linear solid mechanics, particularly in composite material modeling and simulation.

SEMNI O. C. Zienkiewicz award
The highest distinction provided biannually by SEMNI to personalities in the field of numerical methods in engineering is the O. C. Zienkiewicz prize.
In this occasion, the award goes to:

- **Prof. Manuel Doblaré**, from the University of Zaragoza.
  Prof. Manuel Doblaré is a member of the Spanish Royal Academy of Engineering and a renowned specialist in the field of numerical methods, biomechanics and mechanobiology. Prof. Doblaré will receive a diploma and a plaque during the gala dinner of the next Conference on Numerical Methods, CMN, to be held in Guimarães, Portugal, next July 1-3rd, 2019.

Traditionally, SEMNI O. C. Zienkiewicz awardees deliver a plenary lecture during this same conference. In this case, the conference is entitled From Data-Driven modeling to Physically-Constrained Deep Learning in Predictive Continuum Physics, where he will overview the results of his research in the field. ●

ASOCIACIÓN ARGENTINA DE MECÁNICA COMPUTACIONAL

AMCA

MECOM 2018
XII Argentine Congress on Computational Mechanics
Tucumán, Argentina
6 - 9 November 2018

The XII Argentine Congress on Computational Mechanics (MECOM 2018) took place from November 6 to November 9, 2018, in the city of Tucumán, Argentina. This new edition of the annual AMCA Congresses was organized by Faculty of Exact Sciences and Technology (FACET) of the National University of Tucumán (UNT), together with the Argentine Association of Computational Mechanics, AMCA.

Figure 1:
MECOM 2018 opening ceremony

The organizing committee was chaired by Dra. Bibiana Luccioni and integrated by: Sergio Gutierrez, Sonia Vrech, Facundo Isla, Gabriel Araoz, Martín Almenar and Javier Danna. The Scientific Committee was chaired by Dr. Guillermo Etse.

The Congress included nine invited lectures by:
Prof. M. H. Ferri Aliabadi (Imperial College, England),
Dr. Jan Červenka (Červenka Consulting, Czech Rep.),
Prof. Peter Hagedorn (Friedrich-Alexander-Universität, Eriangen-Nürnberg, Germany),

Figure 2:
Welcome cocktail at MECOM 2018

AMCA Awards 2018

The ceremony of the AMCA Awards 2018 took place during the Congress Banquet of MECOM 2018

The award for Young Researchers was granted to **Antonio Caggiano**, form LMNI, University of Buenos Aires, Argentina.
The award for International Researchers was for **Luis Caffarelli**, from Universityof Texas at Austin, USA. ●

Figure 5:
The AMCA President, Victor Fachinotti (left) delivers the Young Researcher Award to Antonio Caggiano

Prof. Sergio R. Idelsohn (CIMNE-UPC, Spain),
Prof. Eddie Koenders (Technische Universität Darmstadt, Germany),
Prof. Rainald Lohner (George Mason University, USA),
Prof. Anna Pandolfi (Politecnico di Milano, Italy),
Prof. Areti Papastavrou (Dept. Mech. Engng. and Building Services Engng, Germany),
Prof. Paul Steinmann (Friedrich-Alexander-Universität Eriangen-Nürnberg, Germany).

The Congress was held at the Campus of UNSTA (Saint Thomas Aquinas North University), at Yerba Buena, and was attended by 250 professionals and students of the field, from Argentina, Brazil, Chile, Germany, Colombia, Uruguay, Finland, Czech Republic, USA, Italy, Spain, and England. Full-length papers were submitted to a review process prior to publication. Accepted papers have been published in the proceedings, which are openly available at the website:
http://www.amcaonline.org.ar/mcamca

A special session was devoted to undergraduate students, with awards for the best posters.

The Congress also included other activities, as the VIII Meeting of OpenFOAM users, and the ceremony of AMCA Awards 2018 during the MECOM2018 banquet. ●

Figure 3:
Posters session at MECOM 2018

Figure 4:
Participants at MECOM 2018

ENIEF 2019
XXIV Congress on Numerical Methods and their Applications

November 5-7, 2019
Santa Fe, Argentina

CALL FOR PAPERS
The Argentine Association for Computational Mechanics (AMCA) announces the XXIV Congress on Numerical Methods and their Applications (ENIEF 2019), which will be held at Santa Fe, Argentina, organized by the Research Center for Computational Methods (CIMEC) and AMCA.
http://enief2019.amcaonline.org.ar ●

conference diary planner

28 Jul - 1 Aug 2019 **USNCCM 15 - 15th US National Congress on Computational Mechanics**
Venue: Austin, TX, USA *Contact:* http://15.usnccm.org/

21 - 23 Aug 2019 **Recent Advances in the Modeling and Simulation of the Mechanics of Nanoscale Materials,**
Venue: Philadelphia, PA, USA *Contact:* http://15.usnccm.org

28 - 30 Aug 2019 **8th GACM Colloquium on Computational Mechanics***Venue:*
Venue: Kassel, Germany *Contact:* www.uni-kassel.de/go/gacm2019

1 - 6 Sept 2019 **YIC 2019 - Eccomas Young Investigators Conference**
Venue: Cracow, Poland *Contact:* http://www.ptmkm.pl/pl/node/134

3 - 5 Sept 2019 **COMPLAS 2019 - XIV International Conference on Computational Plasticity**
Venue: Barcelona, Spain *Contact:* http://congress.cimne.com/complas2019/

8 - 12 Sept 2019 **PCM-CMM 2019 - 4th Polish Congress of Mechanics &**
23rd International Conference on Computer Methods in Mechanics
Venue: Krakow, Poland *Contact:* http://pcm-cmm2019.com/

11 - 13 Sept 2019 **Sim-AM 2019 - II International Conference on Simulation for Additive Manufacturing**
Venue: Pavia, Italia *Contact:* http://congress.cimne.com/sim-am2019/

12 - 14 Sept 2019 **EUROGEN 2019 - Evolutionary & Deterministic Methods for Design, Optimization & Control**
Venue: Guimarães, Portugal *Contact:* http://eurogen2019.dep.uminho.pt/

16 - 18 Sept 2019 **18th International Conference on Fracture and Damage Mechanics**
Venue: Rhodes, Greece *Contact:* http://fdm.engineeringconferences.net/

18 - 20 Sept 2019 **IGA 2019 - VI International Conference on Isogeometric Analysis**
Venue: Munich, Germany *Contact:* http://congress.cimne.com/IGA2019/

18 - 20 Sept 2019 **COMPOSITES 2019 - VII Conference on Mechanical Response of Composites**
Venue: Girona, Spain *Contact:* http://composites2019.udg.edu/

18 - 20 Sept 2019 **MSF4 2019 - 4th International Conference on Computational Methods for Solids and Fluids**
Venue: Sarajevo, Bosnia y Herzegovina *Contact:* http://gf.unsa.ba/eccomas-msf-2019/

1 - 4 Oct 2019 **CMCS - Computational Modeling of Complex Materials Across the Scales**
Venue: Glasgow, UK *Contact:* https://www.eccomas.org/

7 - 10 Oct 2019 **FORM & FORCE 2019 - XI Conf. Textile Composites & Inflatable Structures & IASS Symposuim**
Venue: Barcelona, Spain *Contact:* http://congress.cimne.com/Formandforce2019/

7 - 10 Oct 2019 **CompCancer-2019 - Computational Simulation of Cancer: Molecular and Cellular Dynamics**
Venue: Porto, Portugal *Contact:* https://compcancerconf.wixsite.com/

16 - 18 Oct 2019 **3rd Conf. on Recent Advances in Nonlinear Design, Resilience & Rehabilitation of Structures**
Venue: Coimbra, Portugal *Contact:* https://corass2019.dec.uc.pt/

16 - 18 Oct 2019 **VipIMAGE 2019 - VII Conference on Computational Vision and Medical Image Processing**
Venue: Porto, Portugal *Contact:* https://paginas.fe.up.pt/~vipimage/

28 - 30 Oct 2019 **PARTICLES 2019 - VI International Conference on Particle-Based Methods**
Venue: Barcelona, Spain *Contact:* http://congress.cimne.com/particles2019/

14 - 17 Nov 2019 **XL CILAMCE - Ibero-Latin American Congress on Computational Methods in Engineering**
Venue: Natal, RN, Brazil *Contact:* http://www.cilamce2019.com.br/

20 - 22 Nov 2019 **COCIM 2019 - XVIII Congreso Chileno de Ingeniería Mecánica**
Venue: Talca, Chile *Contact:* http://www.cocim2019.utalca.cl

28 - 30 Nov 2019 **ENIEF-MECOM 2019. XXIV Congreso sobre Métodos Numéricos y sus Aplicaciones.**
Venue: Santa Fe, Argentina *Contact:* http://venus.santafe-conicet.gov.ar/

18 - 21 Dec 2019 **APCOM 2019 - 7th Asian Pacific Congress on Computational Mechanics**
Venue: Taipei, Taiwan *Contact:* http://www.apcom2019.org/

26 - 28 Feb 2020 **Experimental Fracture Mechanics Meets Phase Field and Peridynamics**
Venue: Baton Rouge, LA, USA *Contact:* ruth@usacm.org

19 - 24 July 2020 **ECCOMAS CONGRESS 2020** jointly organized with the
WCCM XIV - 14th World Congress on Computational Mechanics (IACM)
Venue: Paris, France *Contact:* http://www.eccomas.org/

16 - 18 Sept 2020 **SAHC 2020 - International Conference on Structural Analysis of Historical Constructions**
Venue: Barcelona, Spain *Contact:* http://congress.cimne.com/SAHC2020/

19 - 21 Oct 2020 **IGA2020 - Isogeometric Analysis 2020**
Venue: Banff, Canada *Contact:* ruth@usacm.org