Asymptotic methods, mechanics and other applications

Organisé dans le cadre de l'ANR Jeunes chercheurs
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31 août
1 septembre
2009

Conférenciers :

Habib Ammari
Marc Bonnet
Éric Bonnetier
Patrick Joly
Dorothee Knees
Dominique Leguillon
Jean-Jacques Marigo
Vuk Milisic
Saeid Nezamabadi
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www.bretagne.ens-cachan.fr/math/macadam/workshop

Programme

Lundi 31 août

10h00	*Accueil*
10h30-11h15	E. Sanchez-Palencia, Perturbations singulières complexifiantes. Exemples et applications
11h15-12h00	H. Ammari, Asymptotic spectral imaging
12h00-12h45	D. Knees, On the inviscid limit of a model for crack propagation
	Déjeuner
14h30-15h15	D. Leguillon, Singularités 3D vs. singularités 2D – Développements singuliers au voisinage du point intérieur d'un dièdre
15h15-16h00	V. Péron, Skin effect description with a multiscaled asymptotic expansion
	Pause
16h30-17h15	E. Bonnetier, 'Super-resolution' in structured media
17h15-17h45	M. Dambrine, Some mathematical questions studied by Macadam
17h45-18h15	D. Brancherie, From micro-defects to rupture: coupling asymptotic analysis and strong discontinuity approach
20h00	*Dîner au Galopin, 21 avenue Jean Janvier à Rennes*

Mardi 1er septembre

9h00-9h45	K. Schmidt, High order transmission conditions for conductive thin sheets - asymptotic expansions versus thin sheet bases
9h45-10h30	J.J. Marigo, The effective behaviour of (heterogeneous) elastic bodies containing defects localized on a surface
	Pause
11h00-11h45	S. Nezamabadi, Asymptotic numerical method for multiscale buckling analysis of heterogeneous materials
11h45-12h30	P. Joly, Asymptotic models in aeroacoustics
	Déjeuner
14h30-15h15	V. Milisic, Blood flow along and through a metallic multi-wired stent
15h15-16h00	M. Bonnet, Adjoint solution-based small-inclusion asymptotics of cost functions, with application to defect identification
16h30	*Fin des journées*

Résumés – Abstracts

Asymptotic Spectral Imaging

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We will present our recent results on imaging defects, corrosion or inclusion's shape deformations from eigenvalue and associated eigenvector boundary measurements.

Adjoint solution-based small-inclusion asymptotics of cost functions, with application to defect identification

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The identification of hidden flaws in solids and structures is a very challenging type of inverse problem. In this talk, we consider situations where overdetermined data is available on the boundary (e.g. measured displacement on a prescribed-traction surface). A standard approach to such problems is then to formulate and minimize a cost function expressing a misfit between the available observations and their simulation for assumed defect configurations. Such approach however leads to iterative minimization schemes that may entail very high computing costs due to repeated forward simulations, especially when considering 3-D configurations and dynamical measurements.

Motivated by these considerations, we have been developing non-iterative approaches based on the concept of topological sensitivity, which consists in evaluating the perturbation undergone by the cost function due to the hypothetical nucleation of a small defect of prescribed nature and shape at a given sampling location. This perturbation can be evaluated as a function of the sampling location by a bilinear combination of two states (forward and adjoint), that can be computed by any of the standard numerical methods available. The coefficients of this combination are found from an analytical preparatory work where the cost function asymptotics is carried out, and depend on the assumed characteristics of the small defect through a polarization tensor. Qualitative defect identification is then achieved by evaluating the topological sensitivity as a function of sampling locations in a region of interest: lowest negative values of this indicator correspond to locations where the featured cost function will decrease most should a small defect be present there. Various numerical examples (based so far on simulated data) for identification of cavities or cracks 3-D acoustic or elastodynamic media show that this approach indeed provides useful qualitative results (location and number of defects), at a computing cost far lower than a full-fledged iterative inversion. Such results may be used either stand-alone or as good initial guesses for subsequent iterative procedures.

A refinement of this asymptotic approach then consists in expanding the cost function in powers of the size of the trial small defect, beyond the previously-investigated leading contribution. This allows to set up approximate global search techniques, which give better defect size estimates than the previous "simple" topological sensitivity at a computing cost far lower than that entailed by usual global search algorithms. This approach, which requires a substantial analytical preparation work but is then easy to implement, has been so far formulated for

impenetrable obstacles or penetrable inclusions in 3-D acoustic media. The formulation will be presented, and its potential and effectiveness demonstrated on numerical experiments.

'Super-resolution' in structured media

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This talk is motivated by a series of time reversal experiments for electromagnetic waves, performed at ESPCI. These experiments evidenced that the presence of a microstructure of scatterers in the vicinity of the target would cause focusing beyond the diffraction limit. As a model for these experiments, we consider a 2D collection of dielectric scatterers, that are periodically distributed in a bounded region Ω of the plane. The medium has constant dielectric coefficients in the rest of the plane. A dielectric target ω is placed in the interior of Ω. Using small volume asymptotics, we compare the fields away from Ω when the target is present and in absence of the target. We show that the perturbation caused by the target is proportionnal to the gradient of the Green's function of the homogenized model. The response of the medium around the target is thus that of an effective medium, which may explain the improved resolution. This work is a collaboration with H. Ammari and Y. Capdeboscq.

From micro-defects to rupture: coupling asymptotic analysis and strong discontinuity approach

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This work lies in the context of the prediction of the behavior of structures till rupture. Rupture is highly correlated to the presence of defects: material defects, geometrical defects or loading perturbations. In this work, we look more precisely at the prediction of the rupture of complex structures suffering from surfacic singular perturbations. We are concerned by the choice of the most suitable Finite Element strategy to capture the structural behavior. The main feature of our work is to propose an approach dealing both with singular surface perturbations and localization zones development by using a coarse description of the geometry : neither the perturbation shape nor a fine representation of the cohesive crack are considered. Our goal is to design a numerical strategy dealing with a coarse discretization of the unperturbed domain and able to perform the analysis of the structural response from the elastic phase to complete failure. To that purpose, we consider two macroscopic models dedicated to each of the two phases of the behavior.

- The influence of the shape and size of the perturbation is evaluated by an asymptotic analysis for a boundary singular perturbation in an elliptic boundary value problem. A strong use of linearity of the Navier equations is made to evaluate the influence of the defect through a superposition technique. The problem to be solved naturally involves two scales: the structural scale and the perturbation scale. The solution is then approximated by the superposition of the solution of the unperturbed problem at the structural scale and of a linear combination of profiles solving Navier equations at the scale of the pertubation. We propose a FE strategy based on a kinematic enrichment of standard finite element

techniques through the partition of unity. The profiles computed from the asymptotic analysis are added to the discrete variational space so that we can reach a fine description of the stress state around the perturbation while using a coarse mesh adapted to the unperturbed domain.

- The description of the localization zones development is provided by the use of a strong discontinuity approach. Strain localization zones are then taken into account through the introduction of displacement discontinuity surfaces without any need of a fine description of the localization zone. The physical features of the failure process are accounted for by considering adequate discrete type models linking the traction on the discontinuity to the displacement jump. Numerically, such discontinuities are taken into account by enhancing the shape function basis by an Heaviside function through the incompatible mode methods.

The key point of the presented approach is to propose a field transfer strategy allowing to couple the enrichment deduced from the asymptotic analysis and the strong discontinuity method. The discrete variational spaces being different we propose a strategy based on energy criteria to project the field from one discrete space to the other one. The proposed strategy and its implementation are presented and illustrated through various examples.

Some mathematical questions studied by MACADAM

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The presence of small inclusions or surface defects alters the solution of the Laplace equation posed in a reference domain. If the characteristic size of the perturbation is small, one can expect the solution of the problem posed on the perturbed geometry to be close to the solution of the reference shape. An asymptotic expansion with respect to that small parameter (the characteristic size of the perturbation) can then be performed. The techniques rely on the notion of profile, a normalized solution of the Laplace equation in the exterior domain obtained by blow-up of the perturbation. It is used in a fast variable to describe the local behavior of the solution in the perturbed domain. Convergence of the asymptotic expansion is obtained thanks to the decay of the profile at infinity.

I will present two directions of research we followed in the ANR project MACADAM.

- First, I will briefly talk about the case of multiples inclusions, in particular about the intermediate cases, where the inclusions are moderately close, i.e. the distance between them is a third intermediary scale between the size of the inclusion and the size of the whole object. One can expect to have a weak interaction between the two inclusions. In a joint work with V. Bonnaillie-Noël, S. Tordeux and G. Vial, we have quantified this effect and provided a complete asymptotic description of the solution of Laplace equation.

- In a second time, I will talk about the numerical computation of the profile. In order to obtain an accurate computation, we have looked for a transparent boundary condition for an exterior boundary value problem in planar linear elasticity. The goal is to bound the infinite domain by a large "box" to make numerical approximations possible (typically a large ball of radius R). The solution of the problem set in this bounded domain has to be close to the original solution; the convergence is expected as R goes to infinity. Precisely,

with D. Brancherie, V. Bonnaillie-Noël and G. Vial, we have considered the case of a linear elastic material in the exterior of a bounded domain on the boundary of which the displacement is prescribed. In that case, cancelling the leading singular parts at infinity of the solution leads to an approximate boundary condition of Ventcell's type set on the circle of radius R. The physical parameters E and ν are such that the quantity in front of the Laplace-Beltrami operator is nonnegative. In that case, the usual variational approach for treating Ventcell's boundary condition is not at hands. With V. Bonnaillie-Noël, F. Hérau and G. Vial, we proved that a similar problem for Laplace equation is well posed provided the truncation radius R is chosen big enough.

Asymptotic models in aeroacoustics

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In many applications in aeroacoustics, in particular in aeronautics, it is important to simulate the interactions of acoustic waves with boundaries (walls, wings,...). Moreover, boundary layers of very small width are present close to the boundaries.

The question of a satisfactory treatment of boundaries in aeroacoustics remains essentially open. In this work, we study acoustic wave propagation in a thin duct, in the presence of a laminated flow, a problem which can be seen as a first step towards the treatment of such boundary layers.

We use an asymptotic analysis when the width of the duct is small with respect to the wavelength, which amounts to a low frequency analysis, assuming that the Mach profile of the flow is obtained by a scaling of a reference profile $M(y)$. We establish a limit model and study its well-posedness. On the one hand, we exhibit some profiles for which the model is strongly ill-posed and obtain, as a by-product, new instability results for compressible linearized Euler equations.

On the other hand, we establish sufficient conditions on $M(y)$ for the model to be well posed: the weak well-posedness of the Cauchy problem is obtained via a quasi-explicit representation of the solution, using the Fourier-Laplace transform in space-time. Numerical illustrations will be presented. Finally, we shall show how these results can be used to construct effective boundary conditions for boundary layers.

On the inviscid limit of a model for crack propagation

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The Griffith criterion is an energetic fracture criterion which is frequently applied to decide whether a preexisting crack in an elastic body is stationary for given external forces. Moreover, there is a great number of models which rely on the Griffith criterion and describe the time evolution of a crack. In this lecture we model the evolution of a single crack as a rate-independent process based on the Griffith criterion and discuss different possibilities for setting up such models. We focus on two approaches, namely a model based on global energy minimization (elastic energy + dissipation) and a model based on a local description involving the energy

release rate. We prove existence of solutions for both models using a viscous regularization in the latter case. Finally we present an example which sheds light on the different behavior of the presented models. The example shows that the local description seems to be more adequate to describe the behavior of a crack.

Singularités 3D vs. singularités 2D – Développements singuliers au voisinage du point intérieur d'un dièdre

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Les solutions élastiques au voisinage d'un dièdre rentrant peuvent être décrites par un développement de type Williams composé de termes en puissance de la distance à un point de l'arête du dièdre. Ce développement a une structure particulière due à l'invariance du problème par translation parallèle à l'arête. Certains termes, appelés solutions particulières, viennent directement des solutions du problème bidimensionnel autour d'un coin entrant, posé sur la section droite du dièdre. Les autres, baptisés ombres, sont déduits des solutions particulières par intégration le long de l'axe parallèle à l'arête du dièdre. Nous montrons [1] que le développement de Williams tridimensionnel est alors équivalent au développement le long de l'arête proposé par Costabel et al. en 2004 [2].

[1] T. Apel, D. Leguillon, C. Pester, Z. Yosibash (2008) Edge singularities and structure of the 3-D Williams expansion, C. R. Mécanique, 336, 629-635.
[2] M. Costabel, M. Dauge, Z. Yosibash (2004) A quasidual function method for extracting edge stress intensity functions, SIAM J. on Math. Analysis, 35(5), 1177-1202.

The effective behaviour of (heterogeneous) elastic bodies containing defects localized on a surface

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Work in collaboration with C. Pideri, Laboratoire d'Analyse Non Linéaire Université de Toulon et du Var, F-83957 La Garde, pideri@univ-tln.fr

We consider a N-dimensional elastic body Ω which contains defects localized on one or a few $(N-1)$-dimensional hypersurfaces Γ. These defects can consist in micro-voids, microcracks, thin damaged zones,... (quasi)-periodically distributed in the neighborhood of the hypersurfaces. Outside this zone, the body is either homogeneous or finely heterogeneous. In this latter case, the heterogeneities are supposed periodically distributed in the bulk. A typical example is that of a fiber bridged crack in a composite material made of unidirectional fibers embedded in a matrix, see [2].
In a first approximation, the localized defects have no effect on the global response of the body. The goal of this work is to calculate their second order effects. Specifically, using a two-scale method based on matched asymptotic expansions [1], we will show that the up to second order

effective behaviour of the body can be described by an energy of the following form (sum of a volume energy and a surface energy):

$$2\mathcal{E}(u) = \int_{\Omega\setminus\Gamma} A^*\varepsilon(u)\cdot\varepsilon(u)dx + \int_{\Gamma}(B^*[u]\cdot[u] + C^*[u].\varepsilon_T(u) + D^*\varepsilon_T(u)\cdot\varepsilon_T(u))\ d\Gamma$$

where A^* denotes the (classical) homogenized elastic coefficients, $\varepsilon(u)$ is the strain tensor, $[u]$ is the jump of the displacement u across Γ, $\varepsilon_T(u)$ denotes the tangential part of the strain tensor on Γ. The (tensorial) coefficients B^*, C^* and D^* characterize the effective behaviour of the localized defects. They are obtained by solving local elastic problems set on a cell representative of the local defects.
The method will be explained and illustrated on several examples.

[1] G. Nguetseng and E. Sanchez-Palencia, Stress concentration for defects distributed near a surface. In: P. Ladevze, Editor, Local Effects in the Analysis of Structures, Elsevier, Wien, New York (1985), pp. 55–74.
[2] R. Abdelmoula and J.J. Marigo. The effective behavior of a fiber bridged crack. Journal of the Mechanics and Physics of Solids, 48(11):2419–2444, 2000.

Blood flow along and trough a metallic multi-wired stent

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In this work we study the hemodynamics in a stented artery connected either to a collateral artery or to an aneurismal sac. The blood flow is driven by the pressure drop. Our aim is to characterize the flow-rate and the pressure in the contiguous zone to the main artery: we perform an asymptotic expansion of these quantities, derive error estimates and define a new set of interface conditions. This provides first order information with respect to ε, the size of the stents' wires: the local velocities and the pressure. In the case of the collateral artery, we obain an explicit formula giving the flow rate through the stent as a function of the pressure data of the problem. In the case of the aneurysm, our approach rigorously proves that: (i) the zeroth order term of the pressure in the sac equals the averaged pressure along the stent in the main artery, (ii) the presence of the stent inverses the rotation of the vortex. In the last part we provide numerical results that confirm and illustrate our theoretical claims.

Asymptotic numerical method for multiscale buckling analysis of heterogeneous materials

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In this work, we propose an efficient numerical technique to analyze the instability phenomena of heterogeneous nonlinear materials where buckling may occur at both microscopic and/or macroscopic scales. Modeling multiscale buckling of heterogeneous materials is a challenging task. The nonlinear problems at the micro and macro levels are usually solved through classical procedures of Newton-Raphson, which are known to break down in presence of instabilities. To address this issue, we combine *the multiscale finite element method* (FE^2) and *the asymptotic*

numerical method (ANM). The ANM is based on an asymptotic expansion of the variable fields. Introducing such expansion in the nonlinear problems at both macro and micro scales results a series of linear problems that must be solved successively. Compared to the FE^2 solved with the classical method of Newton-Raphson, the proposed technique offers the following advantages:

1. In the context of a multiscale finite element analysis, the solutions of the nonlinear microscopic problems are obtained by solving series of linear problems. One straightforward consequence is that a localization tensor can then be constructed for each step and it is the same for all orders of the asymptotic development and an explicit constitutive law can then be constructed at the macroscopic level for each step. Thus, while in the FE^2 method the linearization is only valid at each Newton-Raphson iteration, in our procedure the linearization remains valid along the whole asymptotic step;

2. In the ANM, the response curve is explicitly represented in the form of a vectorial series which is calculated with only one decomposition of the stiffness matrix. This representation with series contains several informations that are inaccessible by the classical algorithms. A great advantage easily is not drawn: the length of each step of calculation is a posteriori estimated;

3. The ANM is a very simple technique for solving problems involving junctions and instabilities, as compared to Newton-Raphson-based methods, where an arc-control procedure is required.

Our technique, named Multiscale-ANM, is tested and illustrated through numerical examples involving local instabilities which have significant influence on the macroscopic behaviour.

Skin effect description with a multiscaled asymptotic expansion

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We study a transmission problem in high contrast media. The three-dimensional case of the Maxwell equations in harmonic regime is considered. We derive an asymptotic expansion with respect to a small parameter related to high conductivity. This expansion is theoretically justified at any order. Numerical simulations in axisymmetric geometry highlight the skin effect and the expansion accuracy.

Perturbations singulières complexifiantes. Exemples et applications

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Nous considérons des perturbations singulières dépendant d'un petit paramètre dont la limite est un problème mal posé au sens d'Hadamard (les conditions aux limites sont inadaptées aux équations). La convergence des solutions a lieu seulement dans des espaces à très faible topologie (dont les éléments ne sont pas des distributions). Le caractère mal posé consiste en quelque sorte de "non unicité locale" près du bord, et les solutions pour de petites valeurs du

paramètre sont "froisées" avec longueur d'onde qui tend vers zéro lentement (comme le log du petit paramètre). Ce type de problèmes apparaissent en théorie des coques minces lorsque les courbures principales de la surface moyenne sont partout du même signe et une partie du bord est fixée et le reste libre. On donnera des exemples numériques et des commentaires.

High order transmission conditions for conductive thin sheets – asymptotic expansions versus thin sheet bases

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Sensitive measurement and control equipment is protected from disturbing electromagnetic fields by thin shielding sheets. We will compare two frameworks for their modelling, both derived for higher orders

- transmission conditions derived by asymptotic expansion in the sheet thickness,
- incorporating thin basis functions which are adapted to the shielding behaviour.

The asymptotic expansion provides a Taylor expansion of the solution with respect to the sheet thickness ε, where we have chosen a scaled conductivity to obtain a physically meaningful limit problem. The terms of the expansion are computed iteratively for any order given that the sheet is smooth. Collecting the terms of the expansion we can construct transmission conditions of higher order. We will consider well-posedness, regularity and convergence in ε.

The approach with thin sheet basis functions accommodates the different behaviour of the solution in thickness direction and along the sheets and is also applicable for high frequencies. We will show that convergence of a desired order in ε can be reached by choosing a particular number N of functions, whereas the error also decreases for a particular thickness when N is increased.
We will compare the benefits, efficiency and limits of the two frameworks within FEM discretisations.
To separate the discretisation error from the modelling error the numerical experiments have be performed with high order finite elements (p-FEM) with curved cells using the Numerical C++ Library Concepts.

Liste des participants

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Informations pratiques

Navette entre la gare TGV de Rennes et l'ENS Cachan-Bretagne

Une navette est mise à la disposition des participants pour les trajets entre la gare TGV de Rennes, Esplanade SNCF sortie SUD (en face de l'hôtel Ibis) et l'ENS Cachan-Bretagne. La durée du trajet est de 25 minutes environ.

Lundi 31 août:	départ à 9h15 de la gare TGV de Rennes départ à 18h30 de l'ENS Cachan-Bretagne
Mardi 1er septembre:	départ à 8h15 de la gare TGV de Rennes départ à 16h30 de l'ENS Cachan-Bretagne

Connexion internet

Le réseau *wifi-ens* est diffusé librement et donne un accès web.

Dîner

Un dîner sera organisé le 31 août à 20h au restaurant Le Galopin, 21 avenue Jean Janvier à Rennes (à proximité de la gare TGV).


Quai Duguay Trouin
Quai Lamartine
Quai Chateaubriand
Quai Dujardin
Avenue Aristide Briand
Quai Lamennais
Quai Emile Zola
Quai de Richemont
Avenue Sergent Maginot
Boulevard de la Liberté
Boulevard de la Tour d'Auvergne
Avenue Jean Janvier
Boulevard Laënnec
Rue Saint-Louis
Place des Lices
Place du Bas des Lices
Place de la Trinité
Place Saint-Michel
Place Rallier du Baty
Place du Champ Jacquet
Halles et salles
Rue Le Bastard
Rue de Brosse
Parlement de Bretagne
Place du Parlement de Bretagne
Rue des Fossés
Préfecture de Région Bretagne
Tribunal Administratif
Cont. de la Motte
Square de la Motte
Rue Martenot
Collège et Lycée Anne de Bretagne
Ville de Rennes
Ecole Elémentaire Duchesse Anne
Allée Guillon
Allée Verlaine
Rue de Paris
Rue Victor Hugo
R. de Toulouse
R. la Fayette
R. Nationale
R. d'Estrées
R. Salomon
Al. R. du Baty
R. Rallier du Baty
R. Lepeudry
R. du Champ Jacquet
R. de la Monnaie
St-Sauveur
Rue Cisson
R. Du Guesclin
R. de l'Hermine
Rue Brilhac
Rue Saint Georges
Piscine
Pompiers
Palais Saint-Georges
Al. Glezen
Services Municipaux
Rue Poullain
Ecole Maternelle Duchesse Anne
Boulevard de Châteaudun
Rue Louis Postel
Rue Kléber
Rue Paul Bert
R. F. Bizette
R. de Belfort
R. Leconte
Rue Nantaise
Portes Mordelaises
R. des Portes Mordelaises
Rue de Juillet
R. de la Cathédrale
Cathédrale St-Pierre
R. St-Guillaume
R. de la Psalette
R. du Griffon
R. du Chapitre
DRAC
Rue Montfort
R. de l'Horloge
Hôtel de Ville
Place de la Mairie
Opéra de Rennes
R. E. Cavell
Eglise St-Germain
Rue Corbin
Rue Gambetta
Rue du Sergent Guilhard
Rue de Viarmes
Place Saint Germain
CDAS Kléber
Place du Calvaire
R. Beaumanoir
R. F. Buisson
Rue Coëtquen
R. du Vau St-Germain
Rue des Francs Bourgeois
Rue des Dames
CCAS
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Rue Dupont des Loges
Place de Bretagne
Rue de la Chalotais
Rue du Pré-Botté
R. du Pré-Botté
R. de la Parcheminerie
R. du Champ Dolent
Théâtre ADIL
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Rue Lanjuinais
Rue de Nemours
Rue Jules Simon
Rue Vasselot
Rue Maréchal Joffre
R. PL Courier
R. du Cap. Dreyfus
R. des Carmes
Eglise Toussaints
Lycée et Collège Emile Zola
Ecole Elémentaire Liberté
Rue Saint-Thomas
Rue du Dic
Cité Administrative
Square Kergus
Place H. Commeurec
Halles Centrales
Temple
Collège de la Tour d'Auvergne
Rue de la Santé
Rue de Motte Picquet
EDF GDF
Rue Chicogné
Rue du Pré-Perché
Square du Pré-Perché
Rue de l'Arsenal
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Rue du Vieux Cours
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URSSAF Séc. Sociale Allocations Fam.
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Services Techniques Municipaux
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Rue Thiers
Groupe scolaire Louise Michel
Rue du Puits Mauger
Place du Général Kœnig
Jardin du Papier Timbré
Rue de Plélo
Esplanade du Général de Gaulle
Place Gal Giraud
Rue d'Isly
DRASS
Cours des alliés
Boulevard Magenta
R. Aubry
Rue Duhamel
Avenue Louis Barthou
Boulevard des Français Libres
Square des Français Libres
Maison du Champ de Mars Chambre de Métiers
OSCR CIJB
MCE
CNFPT
Esplanade du Champ de Mars
Boulevard Solférino
Gare Routière
Place de la Gare
Gare SNCF
Rue Gurvand
Boulevard de Beaumont
Rue Raoul Dautry
Rue de l'Alma
Mail Albert Einstein
Place des Colombes
Crèche
Rue du Papier Timbré
Square du Roi Arthur
Place du Colombier
Perception INSEE
Place Maréchal Juin
Mail Anne Catherine
Notoriat
Ste Famille
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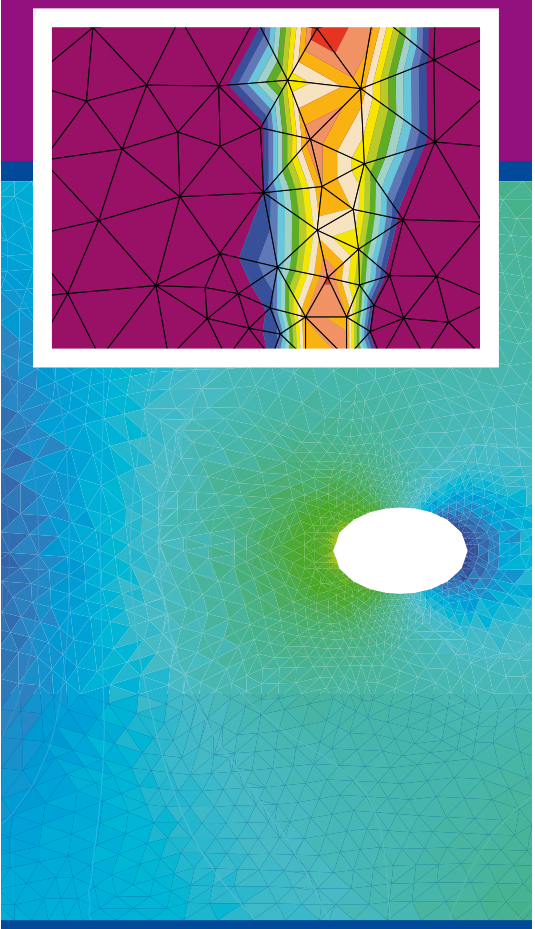
R. Docteur F. Joly
Allée Viaud
Foyer P. A.
Place du 50e d'Artillerie
Square des Martyrs de la Résistance
Square Emile Souvestre
R. du Capitaine Maignan
Rue du 10e R.A.
Rue Théophile Briant
La Poste
Boulevard du Colombier

PLAN DE SITUATION
Campus de Ker Lann



Ce workshop vise à réunir des chercheurs des communautés de la mécanique numérique et des mathématiques pour faire le point sur l'utilisation des méthodes asymptotiques.

En effet, de nombreuses situations physiques conduisent à considérer des objets dont la géométrie présente naturellement plusieurs échelles. À la description macroscopique s'ajoute un niveau de détail microscopique : c'est le cas de bulles de gaz au sein d'un matériau obtenu par fusion, de granulats dans un bloc de béton ou d'aspérités à la surface d'une carrosserie. Les problématiques concernent notamment les propriétés mécaniques et électromagnétiques de ces matériaux. Il est difficile de prendre en compte plusieurs échelles en particulier dans la résolution numérique. L'un des enjeux de ce workshop est de présenter quelques résultats récents d'applications des méthodes asymptotiques.

Comité scientifique et d'organisation

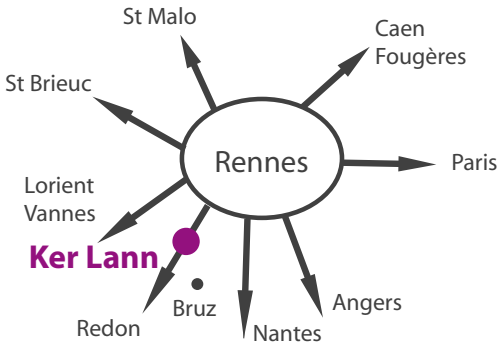
- **Virginie Bonnaillie-Noël,**
  IRMAR, ENS Cachan - Bretagne
- **Delphine Brancherie**
  ROBERVAL, Université de Technologie de Compiègne
- **Marc Dambrine**
  LMA, Université de Pau et des Pays de l'Adour
- **Sébastien Tordeux**
  IMT, INSA Toulouse
- **Grégory Vial**
  IRMAR, ENS Cachan - Bretagne

Informations pratiques

Sur le site du workshop :

- **Inscription** gratuite, mais obligatoire, à partir du mois de mai
- Liste d'**hôtels**
- Horaires des **navettes** entre la gare de Rennes et l'ENS Cachan - Bretagne.

Plan d'accès



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