New mathematics for a safer world: wave propagation in heterogeneous materials

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Abstracts

Abrahams, I David
Improved convergence of eigenfunction expansions and its use for tamper detection of cargo containers
Tamper detection of containers is a critical element in arms treaty verification procedures. Such detection methods have to be robust and easily employed in situ, and hence ultrasonic elastic wave approaches tend to be favoured. The present project has explored several canonical models for mode conversion in thin plates, which appear to offer a useful way to detect tamper in the walls of containers. These models, as for most waveguide problems in acoustics, electromagnetism, and elasticity, have solutions that are expressible as an infinite sum of discrete modes (or eigenfunctions). Standard techniques may be employed to determine the scattered field induced by waves impinging on a geometric discontinuity, edge or other inhomogeneity, and these approaches often reduce to finding the modal coefficients from an infinite linear system of equations. Unfortunately, it is well known that in many cases the convergence of such systems is very slow, so that very large truncated systems have to be taken to ensure an accurate solution. Many methods have been proposed to improve convergence; however, this talk will demonstrate how an a priori understanding of the physical solution close to corners or other irregularities can be used to dramatically improve the convergence. For ease of exposition the procedure will be demonstrated by recourse to several simple model problems. Co-authors: Robert Davey (University of Manchester) and Raphael Assier (University of Manchester).

Aleshin, Vladislav
Modelling of acoustic waves and vibrations in materials containing frictional cracks with rough faces
Modelling of elastic deformations in materials containing frictional cracks of known configuration is possible via modern finite element methods. However, it is necessary to define boundary conditions at crack faces considered as additional (internal) boundaries. The classical Coulomb friction law for flat contact surfaces does not provide explicitly the desired load-displacement relationship. Indeed, once the threshold condition is reached, the tangential displacement becomes undefined. Therefore we use another approach in which contact displacements are considered as arguments and not functions. This has been done for contact between rough surfaces. Surface relief engenders a partial slip regime (absent for flat faces) and makes it possible to express the tangential displacement as a sum of partial slip and total sliding components. The partial slip regime corresponds to the Hertz-Mindlin problem of contact between two spheres with friction, except that its solution should be extended for rough surface geometries and arbitrary loading histories. We build up this extension using the previously developed method of memory diagrams and finally obtain a semi-analytical load-displacement solution to the contact problem. The algorithm has been integrated into the COMSOL solid mechanics unit. We present several examples produced by our numerical code and also provide nonlinear analysis.

Baronian, Vahan

Imaging defects in an elastic waveguide using time-dependent surface data

We propose here a method for imaging defects in an elastic cylinder of arbitrary cross section, from points measurements realized on the exterior surface, in the time domain. This method takes advantage of the multimodal behaviour of guided waves in order to image a given interior region of the structure.

For this purpose, several measurements associated to a source occupying different positions on the surface are realized. Then, a Fourier transform is performed on those data to come back in the harmonic regime. On selected frequencies of the spectrum, a measurement matrix is built, where coefficients correspond to a single component of the scattered fields associated to given source and measurement points. It is shown that the scattering matrix is related to this measurement matrix by inverting a system involving a reception and an emission matrices, whose conditioning can be analyzed and optimized.

It is then possible to apply the Linear Sampling Method (LSM) in a modal formulation, the resolution of which leads to a characteristic function of the defect at each frequency, which gives an image of the sampling domain. Combining several frequencies can enhance the identification of the defects compared to those obtained at a single frequency.

Barucq, Hélène

Using Trefftz-DG numerical methods for solving wave equations in heterogeneous media

Finite Element (FE) approximations of the Helmholtz equation may lose their accuracy when the size of the computational domain exceeds several hundreds of wavelength. This is the so-called pollution effect and it can be mitigated by increasing the density of discretization nodes. Discontinuous Galerkin methods have demonstrated a better efficiency than continuous ones but they still require a very high number of nodes. Hybridized versions of DG (HDG) methods have been proposed to address this issue and they have been implemented with local polynomial basis functions. In this work, we propose a DG method which involves local solutions to the Helmholtz equation computed thanks to a boundary element method. A series of numerical experiments displays an excellent stability of the method and more importantly its outstanding ability to reduce the instabilities corresponding with the "pollution effect" on numerical simulations of long-range wave propagation.

Bellis, Cédric

Defect identification using topological sensitivity approaches and piezoelectric transducer modelling

The focus of this presentation is the transient wave-based detection and identification of defects embedded in isotropic elastic solids using piezoelectric transducers. This work addresses this problem within a comprehensive framework encompassing description of elastic wave propagation within the probed media as well as consideration of the coupling phenomena induced by the transducers. A fundamental reciprocity identity associated with a quasi-static piezoelectric model is derived to lay the foundations of ensuing developments and approach of this inverse scattering problem. Modelling of piezoelectric transducers is discussed and application of the proven reciprocity theorem enables the proposition of an iterative construction procedure of electric inputs generating waves expected to focus on the sought defects. The characteristic features of the inverse problem considered, which uses piezoelectric sensor-based measurements, are also discussed. Next, the identification problem is investigated by way of an adjoint field-based topological sensitivity approach that permits the construction of a defect indicator function based on the derived reciprocity identity. For simplicity of exposition, the studied configurations involve defects in the form of traction-free cavities. Finally, a set of 2D numerical examples based on the spectral finite-elements method is presented to assess the performances of the proposed approach in identifying embedded defects from electric measurements.

Bonnet-BenDhia, Anne-Sophie
Invisible obstacles in waveguides
A localized perturbation of a waveguide maybe invisible at particular frequencies. This means that the interaction of any propagative mode with the defect only produces evanescent modes, which are not detectable in the far-field.

The first question that we consider is the following: for a given frequency, how to design invisible perturbations of as large magnitude as possible? The idea that we have developed is to use theoretical results of asymptotic analysis in order to choose a clever parametrization of the perturbation (its shape and/or its material coefficients), with as many parameters as the number of measures. Then the invisibility is simply expressed as a fixed-point equation on the parameters.

Conversely, we want to determinate for a given perturbation the spectrum of frequencies for which invisibility occurs. This leads to an unexpected relation between invisibility and trapped modes. The two questions will be investigated in the simple case of a 2D acoustic waveguide.

Borcea, Liliana
Wave propagation in random waveguides with turning points
Guided waves arise in a variety of applications like underwater acoustics, optics, the design of musical instruments, and so on. We present an analysis of wave propagation and reflection in an acoustic waveguide with random sound soft boundary and a turning point. The waveguide has slowly bending axis and variable cross section. The variation consists of a slow and monotone change of the width of the waveguide and small and rapid fluctuations of the boundary, on the scale of the wavelength. These fluctuations are modelled as random. The turning point is many wavelengths away from the source, which emits a pulse that propagates toward the turning point, where it is reflected. We consider a regime where scattering at the random boundary has a significant effect on the reflected pulse. We determine from first principles when this effects amounts to a deterministic pulse deformation. This is known as a pulse stabilization result. The reflected pulse shape is not the same as the emitted one. It is damped, due to scattering at the boundary, and is deformed by dispersion in the waveguide. An example of an application of this result is in inverse problems, where the travel time of reflected pulses at the turning points can be used to determine the geometry of the waveguide.

Capdeville, Yann
Homogeneization and the elastic full waveform inverse problem
Homogenization for wave propagation in deterministic media with no scale separation, such as geological media, has been recently developed. With such an asymptotic theory, it is possible to compute an effective medium valid for a given frequency band, such that effective waveforms and true waveforms are the same up to a controlled error. So far, this method has been mainly used as a pre-processing step to simplify complex media to reduce the forward modelling numerical cost. Nevertheless, for the inverse problem, it raises an interesting point: for a given dataset and a given frequency band, two models are now solution of the full waveform inverse problem (FWI): the true model and the homogenized model. Because homogenized models belong to a finite dimensional space (which is not the case of potential true models), we claim it is easier (and probably the only option) to search for a homogenized model than for a true model. In this work we investigate this idea of a FWI constrained by homogenization.

Collison, Ian
Materials characterisation through ultrasonic inspection
Ultrasound is most often used to assess structural integrity of components by detecting and characterising defects. However, ultrasonic methods capable of characterising the material itself are of significant interest also.

SRAS – Spatially resolved acoustic spectroscopy is one such example technique that can image material microstructure by using surface acoustic wave (SAW) velocity as its contrast mechanism. Other ultrasonic techniques which measure material nonlinearity have been shown to provide high sensitivity to changes in material properties before the onset of a crack. Such techniques have the potential to be used for pre-crack detection, fatigue assessment and bond/interface quality assessments.

Here, the SRAS technique is reviewed along with two different wave-mixing nonlinear ultrasonic methods. The first nonlinear method is laser-based and uses the interaction of two SAWs to provide a measure of material nonlinearity which is dependent on the level of fatigue seen by the material. The second nonlinear method uses the interaction between two bulk waves to assess the quality of diffusion bonds in titanium specimens.

Croxford, Anthony

The ultrasonic diffuse field for NDE

The diffuse field has several advantages for NDE applications, in this talk we will look at several new ways to use the diffuse field and their benefits.

Curtis, Andrew

Imaging solid media using Marchenko methods and multiply-scattered waves

Using waves to image the interior of solid media that contains strongly scattering heterogeneities is challenging. Waves that scatter multiple times reduce the efficacy of standard imaging methods that require single-scattering-only data (often called focussing or migration methods). Marchenko methods solve this imaging problem for 3D heterogeneous media for which waves can be separated into up- and down-going components at each image point. I will present recent results which use synthetic and real data to compare Marchenko methods to traditional, single-scattering methods of imaging: Marchenko methods produce significantly better images.

Deschamps, Marc

Interaction of guided waves with cracks in an embedded multilayered anisotropic plate by a boundary element approach

In this work, it is solved the problem of the interaction of a transient guided elastic wave by a planar crack with an indirect Boundary Element Method in the Laplace domain. The key point of the method is to calculate rapidly and accurately the Green function for layered plates. The fields are transformed in 2D Fourier wave-vector domain for the space variables related to the plate surface. Surprisingly, this method has been very little used in the ultrasonic community, while it is a useful tool, which complements the much more used technique based on generalized Lamb wave decomposition. By avoiding mode analysis - which can be problematic in some cases - exact numerical calculations (approximations by truncating series, that may be poorly convergent, are not needed) of Green function can be made in a relatively short time for immersed plates and viscoelastic layers. Numerical results show the effectiveness of this method. The examples presented emphasis the quality of the model and the robustness of the algorithm. Comparisons with finite element show excellent agreement. This approach is fast and low memory consuming for planar defects in arbitrary layered media, and can be extended to arbitrary shapes and boundary conditions for a higher computational cost.

Galetti, Erica

Nonlinear tomography for subsurface imaging

Within a typical geophysical exploration or monitoring scenario, data are acquired at the Earth's surface or within boreholes, and inversion might be carried out in order to recover the subsurface properties of interest from the recorded quantities. Traditionally, geophysical inversion methods use iterated, linearised schemes which produce a solution that best fits the observed data. Although computationally fast, such methods are unable to provide an accurate representation of solution uncertainty, and model solutions are often affected by artefacts related to the linearisation of the physics of the forward problem. Within this talk I will present a fully nonlinear tomography method which uses Bayesian theory, the reversible-jump Markov chain Monte Carlo algorithm, and model parameterisation with Voronoi cells to produce a fully probabilistic solution represented by an ensemble of valid models which are distributed according to the posterior probability density function. The uncertainty of the solution can be evaluated directly from the ensemble, and solving the forward problem at each Markov chain iteration ensures that the physics of the forward problem is never linearised. Examples will include 2D and 3D applications to seismic and electrical resistivity tomography.

Gower, Artur

Characterising random media from backscattering: measuring number fraction and inclusion radius

Acoustic wave measurements are quick and non-invasive. They can be ideal to characterise composites, when we can accurately interpret the acoustic signals. However, for a wide range of frequencies, interpreting the signal is complicated as the field will be subjected to multiple scattering. We introduce a new data driven approach to characterise composites via acoustic backscattering. There are two major challenges in a data driven approach. First we need a large amount of data of backscattered waves from well characterised composites. Second, is how best to use this data to characterise unknown composites. In this talk we address both these challenges, and use simulated 2D data to demonstrate our method.

Our methodology can be used to characterise many features of the medium in question, but for simplicity we make a number of assumptions: the medium is formed from two materials; one material forms a large number of scatterers (all with approximately the same radius) embedded in a uniform background material. Characterising this composite is now equivalent to measuring the volume fraction and radius of the scatterers. To simulate a wide range of volume fractions and scatterer sizes, we use the exact theory for acoustic scattering by identical circular cylinders.

Leger, Alain

Wave propagation in bonded domains: changing a thin layer into a surface

Particular cases of heterogeneous media are the so-called bonded domains, which generically consist of two elastic bodies connected by a thin deformable layer, these different parts being respectively referred to as the adherents and the adhesive. From a physical point of view, the subdomains are all three-dimensional, but one of them, the adhesive, has a spatial dimension which is very small with respect to the others. On the one hand, this leads to difficulties for numerical calculations which either are ill-conditioned due to too strong discrepancy in the element size or would require prohibitive computation time, especially in dynamics. On the other hand, studies in physics or acoustics essentially use jumps across the thin layer without theoretical justifications.

This lecture starts from the fact that rigorous justifications of a transmission condition have been obtained in the case of equilibrium problems through the convergence of the solution in a family of problems in which the layer is thinner and thinner, tending to zero. This is classical. In the case of dynamical problems it is now stated that the convergence results from the one of the static case. Applied here to bonding problems, this result is backed up by Trotter's theory of convergence of semi-groups, of which an important part of the lecture will recall accurately the main steps.

The extension to the case where the behaviour of the adhesive is given by a maximal monotonous graph, which includes a wide range of physical behaviours, ranging from viscoelasticity to models of debonding or delamination, micro-cracks or plasticity, can be performed using the same tools together with a nonlinear version of Trotter's convergence theorem.

Lombard, Bruno

Modelling of nonlinear waves in solids with slow dynamics

In heterogeneous solids such as rocks and concrete, the speed of sound diminishes with the strain amplitude of a dynamic loading. This decrease known as "slow dynamics" occurs at time scales larger than the period of the forcing. Also, hysteresis is observed in the steady-state response. In this presentation, a 3D model of continuum is proposed in the framework of the finite strain theory. An internal variable that describes the softening is introduced, as well as a family of evolution equations for the internal variable. The new model is thermodynamically admissible and dissipative (inelastic). In the case of one space dimension and small deformations, it is shown analytically that the model reproduces qualitatively the main features of real experiments. A finite volume method using Roe linearization is also developed for the system of partial differential equations. The solution to the Riemann problem is well captured by the numerical method. The numerical results show qualitative agreement with experimental results of dynamic acoustoelastic testing (DAET)

Marzani, Alessandro

Locally resonant metabarrier to open surface waves band gaps at seismic length scale

The aim of the talk is to discuss the potential of metamaterials for earthquake mitigation applications. In particular, the idea of a "metabarrier", consisting of an array of single-mass resonators of subwavelength dimensions and buried at the soil surface, is proposed. The metabarrier has proven to be effective in generating a band gap (BG) for surface Rayleigh waves. Within the BG frequency region surface waves are partially converted into shear bulk waves that leave the soil surface and dissipate in the depth of the soil, resulting in a significant ground motion attenuation.

The work investigates also the use of multi-mass resonators to design effective metabarriers characterized by a reduced number of resonators as well as it proposes an optimization scheme, based on Genetic Algorithms, to design a multi-mass resonator with minimal mass able to target selected frequencies as those of some framed structures.

Mercier, Jean-François

Homogenization of an array of air bubbles in water with Minneart resonance

A single bubble of air in water is known to produce a resonance, termed Minnaert resonance, for an incident wavelength much greater than the bubble radius. This subwavelength resonance has been used to build metascreen, composed of a periodic or random arrangement of bubbles along a plane. Such screens produce strong effect on an incident wave near the resonance of a single bubble; this is known since the Alberich project, where similar devices (called anechoic tiles) were applied to the outer hulls of submarines, resulting in the absorption of the sound of active sonar.

We present the 3D homogenization of a 2D array of such screen in the periodic case. In the low frequency regime, we define the small parameter kh, with k the wavenumber and h the array spacing. Appropriate scalings of the physical and geometrical parameters with respect to kh allow us to identify the mechanism of the subwavelength resonance.

The homogenization is based on a multiple scale expansions, specifically 3 scales are needed: The microscale of the bubble whose size is much smaller than the spacing array, the mesoscopic scale of the array where the bubbles are reduced to points presenting a singular behaviour, and the macroscopic scale far from the array where the array is reduced to an equivalent interface.

The homogenization process leads to effective jump conditions across this equivalent interface, involving effective parameters among which one is frequency dependent and encapsulates the resonance.

Niederleithinger, Ernst

Detecting subtle changes in concrete constructions by ultrasound and coda wave interferometry

Monitoring the ageing concrete infrastucture for changes is of high importance for asset managers and the public. Conventional approaches are global methods as modal analysis or locals sensors , e.g. strain gauges. We try to fill the gap by active ultrasonic monitoring using embedded transducers. Various methods are used for feature extraction to detect sudden or subtle changes in the construction. For slowly developing damage mechanisms coda wave interferometry has been shown to be suitable. Main challenge is to attribute the detected velocity changes to a specific load or damage. The presentation will cover the engineering background, measurement technology, data evaluation as well as lab and field results.

Pagneux, Vincent

Scattering of acoustic waves with loss, gain and symmetry

Different aspects of the effects of gain and loss with symmetry on the scattering of acoustic waves will be presented: PT symmetric scattering in flow ducts, perfect transmission resonances and perfect absorption by resonators.

Pham, Kim

Homogenization of resonant interface for wave propagation

We present a homogenization model for a single row of locally resonant inclusions. The resonances, of the Mie type, result from a high contrast in the shear modulus between the inclusions and the elastic matrix. The presented homogenization model is based on a matched asymptotic expansion technique; it slightly differs from the classical homogenization, which applies for thick arrays with many rows of inclusions (and thick means large compared to the wavelength in the matrix). Instead of the effective bulk parameters found in the classical homogenization, we end up with interface parameters entering in jump conditions for the displacement and for the normal stress; among these parameters, one is frequency dependent and encapsulates the resonant behaviour of the inclusions. Our homogenized model is validated by comparison with results of full wave calculations. It is shown to be efficient in the low frequency domain and accurately describes the effects of the losses in the soft inclusions.

Pichugin, Aleksey

Direct asymptotic modelling of sources of laser-generated ultrasound

It is well known that a laser irradiating an elastic surface can serve as a useful standard source of ultrasound. Its benefits include non-contact nature of the excitation as well as the high repeatability of the generated disturbance. As long as the amount of heat deposited by the laser remains sufficiently low, so that the surface does not undergo irreversible damage due to ablation, the photothermoelastic effect dominates the ultrasound generation. This effect can be modelled in two ways. One popular approach is to assume that the heated surface region is acting as an expanding point volume, which is assumed to be equivalent to a set of two mutually orthogonal surface force dipoles. This model, often referred to as a surface centre of expansion (SCOE) effectively replaces the thermoelastic source by its purely mechanical analogue. The overall agreement between the predictions of SCOE and the far field experimental data is very good; however, it does not describe some features of the response observed experimentally. For example, it does not describe a small spike, often named “the pre-cursor”, travelling at the velocity of longitudinal waves. Another popular approach is to use one of the many competing theories of hyperbolic thermoelasticity to model the interaction between thermal and elastic fields explicitly. While such an approach results in excellent agreement between theory and experiment, the corresponding mathematical formulations tend to be cumbersome, which prevents clear physical interpretation of the response. In this paper we present a direct asymptotic analysis of the fully coupled thermoelastic models for the point and line laser sources. Using the previously described quasi-adiabatic approximation, it is possible to demonstrate that SCOE is, essentially, the leading order “regular” approximation for the laser source. It is also possible to assess, both qualitatively and quantitatively, the nature and the origin of the errors implicit when using SCOE and to clarify some misconceptions in the literature. We also discuss the nature of the associated boundary layer.

Savin, Eric

Kinetic models for sound propagation in unsteady heterogeneous flows

In this research we are interested in deriving analytical models for the propagation of sound in heterogeneous flows. These models have relevance for the development of coherent interferometric imaging methods based on the back-propagation of empirical cross-correlation functions for the localization of sound sources or reflectors in randomly heterogeneous media. Our approach considers characteristic length scales of the acoustic disturbance comparable to the perturbations of the ambient flow, which has in turn time and length scales much larger than the acoustic waves. The derivation is based on an asymptotic analysis in the limit of small acoustic wavelengths. It considers the wave action as the primary kinetic variable. The wave action is conserved along the characteristic rays associated to the convected wave equation as opposed to the acoustic disturbance energy which is partly transferred to the ambient flow.

Schumm, Andreas

From penny shaped cracks to perfectly matched layers

Mathematical modelling has accompanied ultrasonic non-destructive testing since the very beginning, always within the constraints dictated by the numerical computation means available at a given time. At a time when memory was a scare resource and computational power quite limited, analytical beam models for propagation through planar interfaces in homogeneous isotropic media were state of the art, and closed form solutions for the interaction with simple reference reflectors – the nowadays almost forgotten penny shaped crack – were all that was affordable. With apparently unlimited computational power and memory available, the need for many of the formerly essential mathematical considerations to simplify the problem at hand seems to be gone: after all, we are able to model phased array inspections of strongly heterogeneous anisotropic media containing complex defects any day, aren't we? In this presentation, we try to review the (brief) history of mathematical modelling of ultrasound propagation from an industry perspective, with applications in mind, to appreciate where we are now, and to recognize which challenges lie ahead.

Solna, Knut

Beam-wave backscattering in random multi scale media and imaging

We consider waves transmitted and reflected by a complex medium in the case in which the medium has fine scale three-dimensional random fluctuations. We show how we can characterize the statistical distribution of the beam wave in this case. Moreover, we how we can use this characterization in the context of imaging and detection in very complex environments.

Tant, Katy

A transdimensional Bayesian approach for material mapping and image correction

Traditional imaging algorithms within the ultrasonic NDE community typically assume that the material under inspection is homogeneous. However, when the medium is of a heterogeneous or anisotropic nature this assumption can contribute to the poor detection and characterisation of defects. Prior knowledge of the internal structure and properties of the material would allow corrective measures to be taken, resulting in better resolved images of any defects. The work presented here endeavours to reconstruct material maps of industrially representative samples from ultrasonic phased array data. This is achieved via application of the reversible-jump Markov Chain Monte Carlo (rj-MCMC) method: an ensemble approach within a Bayesian framework. The resulting maps are used in conjunction with the total focussing method and the reconstructed flaws are used as a quantitative measure of the success of this methodology.

Treyssede, Fabien

On the modelling of elastic waveguides coupled to infinite media

The modal behaviour of open waveguides, that is, waveguides coupled to infinite media, is far more involved than waveguides in vacuo. In the former case, the modal basis includes continua of radiation modes, which are difficult to manipulate. These continua can be approximated by a discrete set of modes, the so-called leaky modes, of special interest for the non-destructive evaluation of structures.

In this talk, a perfectly matched layer (PML) technique will be used to account for the unbounded nature of the surrounding medium. PMLs are known to be very effective from a numerical point of view as they enable to truncate unbounded problems. Yet their use in conjunction with a modal approach remains unclear. From the forced response problem (waveguides under excitation), it will be shown how the PML modifies the original modal basis and how the contribution of leaky modes is naturally revealed. In the case of a finite PML, a biorthogonality relation that applies to any kind of modes (trapped, leaky and PML modes) will be derived. Based on a semi-analytical finite element method, numerical results will be presented. The role of PML modes regarding the convergence of modal expansions will be discussed.

Tweedie, Andrew

Improving defect detectability in composite components using time domain FEA simulation

Carbon fibre reinforced polymer (CFRP) composites are attractive for many transport applications due to their combination of lightweight and high stiffness. These properties allow designers to make a range of improvements, from reduced carbon emissions through to improved crash safety. However, the heterogeneous nature of CFRP structures, along with their high degree of anisotropy make defects challenging to detect via ultrasonic NDE.

We demonstrate how time domain finite element analysis can be used to assess defect detectability in ultrasonic inspections of typical CFRP components. A major advantage of this approach is that arbitrary component layups can be considered, along with the effects of scattering at resin rich areas, which occur between plies, and at ply drops. We show how this tool can be used to simulate wave propagation through these complex structures, and then use it as a tool to optimise inspection performance.

Van Den Abeele, Koen

Nonlinearity based signal processing for defect detection

When seeking out evidence for nonlinear behaviour, various signal processing techniques can be applied for the comparison of two signals, one being a slight distortion of the other. For instance, the pulse inversion technique compares the responses to two out-of-phase excitation signals. Alternatively, one can compare the response at a finite (nonlinear) excitation amplitude to a scaled response at a very low (linear) excitation, as performed in the scaling subtraction technique. In this report, several numerical as well as experimental examples are given in which these nonlinearity based signal processing techniques are used in practice to visualize damage features in solids.

In view of kissing bond defect detection in friction stir welds, the pulse-inversion method was employed in a contact pitch-catch mode using a chirp signal. B-scan spectral heat maps obtained after pulse inversion allow to easily identify and size damage zones along the weld path. Secondly, the scale subtraction technique will be illustrated in combination with an ultrasonic sparse array SHM system to detect damage locations (impacts and delaminations in CFRP plates) without the need of baseline signals taken on an intact specimen. Finally, we show that the phenomenon of Local Defect Resonance (LDR) can be facilitated and validated using the scaling subtraction technique. (Joint with Jan Hettler, Morteza Tabatabaeipour, Steven Delrue)

Velichko, Alexander

Ultrasonic defect characterisation using parametric-manifold mapping

The aim of ultrasonic non-destructive evaluation includes detection and characterisation of defects, and an understanding of the nature of defects is essential for the assessment of structural integrity in safety critical systems. In general, the defect characterisation challenge involves an estimation of defect parameters from measured data. In this paper the extent to which defects can be characterised by their ultrasonic scattering behaviour is explored. Given a number of ultrasonic measurements, it is shown that characterisation information can be extracted by projecting the measurement onto a parametric manifold in principal-component-space. Moreover, this manifold represents the entirety of the characterisation information available from the possible defects of a given type. The nature of this information is investigated, which provides definitive statements on the defect characterisation performance that is, in principle, extractable from typical measurement scenarios. In experiments, the characterisation problem of surface-breaking cracks and the more general problem of elliptical voids are studied, and a good agreement is achieved between the actual parameter values and the characterisation results. The nature of the parametric manifold enables us to explain and quantify why some defects are relatively easy to characterise whereas others are inherently challenging.

Walton, Jay
An approach to determining material parameters and residual stress from ultrasound interrogation of a nonlinear elastic body
Residual stress and strain play an important role in the mechanics of many engineered and natural materials and structures. This talk presents an approach to determining both material properties and residual stress from ultrasound interrogation in the setting of nonlinear elasticity.

Watson, Francis
Sensing challenges in complex environments: a UK MOD perspective
Defence and security has many sensing and imaging challenges in increasingly complex and heterogeneous environments. These include: through foliage and tree canopies; underground structures; buried or hidden explosives; through-wall imaging; and rough sea clutter, to name a few. Further constraints such as timeliness; sensing at large ranges; size, weight and power; restrictions on operating frequencies; as well as noise and interference all inhibit our sensing ability, and safety is always a critical consideration. We use through-wall imaging to motivate these challenges, such as for aiding hostage situations, with example imagery from both Dstl funded and internal research to highlight some of the difficulties. We also give a brief overview of how Dstl functions as a government research lab and interacts with academia, including current and upcoming funding and collaboration opportunities.