Lectures Descriptions

L#	Title	Authors	Abstract
L1	Getting started with inversion,	P. Le Masson, J. L. Gardarein	Introduction to the inverse approach is made starting by simple examples (solution of a linear system of equations, with noised data, case of a slab, in steady state regime, with either flux or conductivity estimation, parameter and function estimations). The inverse terminology, the pitfalls of inversion (noise amplification effect), as well as the corresponding methodological approach are highlighted. The objective is not to solve these problems but to pinpoint the main crucial points in inverse measurement problems. Other lectures will be used to show how to solve them, with the help of the points studied in the lectures in between.
L2	Advanced measurements with contact in heat transfer: principles, implementation and pitfalls	F. Lanzetta, B. Garnier	The main objective of this lecture is to make the end users aware of the various physical phenomena and especially of the errors frequently met during temperature and heat flow measurement. The lecture is divided in two main parts. In part1 The specificities of temperature measurement in fluid flow will be detailed . In Part 2, phenomena which occur in thermometry with contact will be presented. Then the analysis of systematic errors related to the local disturbance of field temperature due to the introduction of sensors will be emphasized. Advanced measurement with thin film sensors and their manufacturing will be presented followed by the various and advanced methods for heat flux measurement
L3	Basics for linear inversion, the white box case	F. Rigollet, D. Maillet	We present and illustrate the roadmap for a linear parameter estimation problem, in the case when the structure of the model is known ('white box case'). The Ordinary Least Square case is first considered to introduce all the useful tools (sensitivity coefficients, conditioning, etc). We focus then on optimal ways to implement the best estimation through the study of the sensitivity matrix and other matrices depending on it.

L4	Measurements without contact in heat transfer	J. C. Krapez, H. Pron, L. Ibos	Part 1 : Part 2 : The purpose of this lecture is to present the advantages and the difficulties when measuring temperature by radiometry, namely by sensing the radiance of the radiative power emitted by the object under study. Thermometry without contact as with one-color, two-colors or multiwavelength pyrometry will be presented. The specific difficulties of these radiative methods and the procedures to overcome bias error in temperature measurement will be discussed. The amount of thermal radiation emitted by a surface at a given temperature is only a fraction of the blackbody radiance at that temperature. This fraction, which is called the emissivity, is an additional unknown parameter. In passive radiation thermometry, whatever the number of considered wavelengths, one faces an underdetermined problem. In addition, the air path between the sensed surface and the sensor introduces itself additional unknown spectral parameters (the air column partly absorbs the radiance coming from the sensed surface; it also emits, depending on the local temperature). We will present some solutions and warn of some pitfalls related to the problem of emissivity and temperature separation developed in the field of multiwavelength pyrometry and in the field of multiwavelength/hyperspectral remote sensing of the earth.
L5	Non-linear parameter estimation problems	B. Rémy	The aim of this lecture is to present a methodology for enhancing the estimation of parameters in the case on a Non-Linear Parameter Estimation problem (NLPE). After some definitions and vocabulary precisions, useful tools to investigate NLPE problems will be introduced. Different techniques will be proposed for tracking For instance the true degree of freedom of a given estimation problem (Correlation, Rank of sensitivity matrix, SVD, ...) and enhancing the estimation of particular parameters by using either a Reduced model or a Model with some parameters fixed at their nominal values. The resulting reduced model can be unbiased or biased.
L6	Inverse problems and regularized solutions	C. Le Niliot	Whatever the technique used to solve inverse problems we have to face to the ill-posed character of the estimation of functions. One of the techniques to use is the regularization of the solution, these techniques are based on the modification of the cost function. We will present in this course different algorithms related to examples associated to the linear estimation seen in courses 1 and 3. We will describe the numerical techniques based on truncation with a focus on the Singular Value Decomposition method. The other approach is based on the penalization techniques which consist in the cost function modification. These two generic techniques are used to circumvent the difficulty of inversion in the presence of ill conditioned matrices, a result of the ill posed character of the IHCP.

L7	Types of inverse problems, model reduction, model identification	O. Quemener, J. L. Battaglia	First, models involved in practical inversion of measurements are presented and classified. They belong to the white, grey or black box categories. The quantities they are based on are introduced and great care is given to the notation, in order to be able to understand the different causes of errors in the subsequent inversion output. The specific application in heat transfer is considered and the different types of inverse problems are presented. The notions of discretization of the observations and of parameterization of the functions that have to be retrieved through inversion are introduced. In a second part, the special case of modal reduction is discussed. This method allows to greatly reduce the size of the model in case of complex geometry. The principle of this technique is presented. A focus on the AROMM method is carried out. We insist on the necessity to choose a modal base adapted to the physical problem. The different principles of bases reduction are introduced.
L8	Function estimation and Large scale estimation problems	Y. Favennec, P. Le Masson	This lecture presents some commonly-used numerical algorithms devoted to optimization, that is maximizing or, more often minimizing a given function of several variables. The goal is function estimation. At first, some general mathematical tools are presented. Some gradient-free optimization algorithms are presented and then some gradient-type methods are pointed out with pros and cons for each method. The function to be minimized gradient is presented accordingly to three distinct methods: finite difference, forward differentiation and the use of the additional adjoint problem. The last part presents some practical studies where some tricks are given along with some practical examples. Keywords. Optimization, Convexity, Zero-order method, Deterministic method, Stochastic method, Gradient-type method, Conjugate gradient, BFGS, Gauss–Newton, Levenberg–Marquardt, Gradients, Direct differentiation, Adjoint-state

L9	The Use of Techniques within the Bayesian Framework of Statistics for the Solution of Inverse Problems	H. Orlande	The solution of an inverse problem within the Bayesian framework is obtained by statistical inference on the posterior probability density. Such a density is obtained through Bayes' theorem and is proportional to the product of the likelihood function, which models the measurement errors, by the prior distribution, which models the information known about the parameters before the experimental data is available. The focus of this lecture is on Markov Chain Monte Carlo (MCMC) methods. Basic concepts, as well as practical issues regarding the implementation of MCMC methods, are presented. The Metropolis-Hastings algorithm, as well as its alternative version that samples the parameters by blocks, are described in detail. Monte Carlo methods usually involve large computational times. The Approximation Error Model technique and the Delayed Acceptance Metropolis-Hastings algorithm are thus presented, aiming at computational speed up and at making MCMC suitable for inverse problems of practical interest. Keywords : Markov Chain Monte Carlo (MCMC) methods, Metropolis-Hastings algorithm, Approximation Error Model, Delayed Acceptance Metropolis-Hastings algorithm
L10	Invited conference : Shape Optimization in additive manufacturing	Olivier Pantz	The recent development of additive manufacturing or 3D printing sparked the interest for new methods in shape optimization. Classical approaches like SIMP methods or level-set methods do not take full advantages of the capabilities of 3D printers which can build shapes containing details of an order of magnitude smaller than traditional processes. The level of precision reached is such that it permits to produce composite materials, made of small micro-structures. In this context, there is no reason to limit the scoop of possible shapes to the ones containing a single length scale. More optimal solutions could be reached in the set of composite shapes. The homogenization method consists precisely in determining the optimal solution among this extended set of shapes. It requires a post-treatment, called dehomogenization, to build a sequence of genuine shapes containing a growing number of details converging toward the optimal composite. We will present the basic ideas of the homogenization and dehomogenization and some few numerical results in dimensions two and three.