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# MODEL REDUCTION IN INVERSE HEAT TRANSFER PROBLEMS

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## ABSTRACT

Generally, multidimensional Inverse Heat Transfer Problems require huge computing time induced by the large system of equations due to the spatial meshing of the domain. in order to estimate some boundary conditions or heat sources for example, the use of such a large direct Detailed Model (DM) can be very heavy and difficult to handle.

In order to solve such problems, it is proposed to reduce the order of the system before the inversion. A specific method leaning on the identification of the most significant eigenmodes of the studied system is presented. This Modal Identification Method (MIM) is a state space representation that links up the inputs of the system to the outputs under consideration, for instance, temperature data used for the inversion. MIM has been first developed for linear systems [1,2]. Nevertheless, the method has been extended to some cases where nonlinearities are taken into account through specific terms according to the physics of the studied example.

In this lecture is recalled the principle of the computation of RM that is obtained through a minimisation of a quadratic criterion between simulated DM outputs and RM's ones. This first stage corresponds to a parameter estimation problem where several matrices are identified. The obtained RM can then be used in very fast direct simulation. Moreover, in a second stage, this RM is particularly well adapted to inverse problems where boundary conditions or heat sources have to be identified.

This methodology is presented with applications in several cases:
i) linear conduction and forced convection,
ii) nonlinear conduction,
iii) natural convection.

The following example examples are given:
1. A simple 2D diffusion example illustrates the reduction approach: from an original mesh, a RM linking two heat flux densities to two sensors is obtained and validated by comparison with DM. Then the two heat flux densities are estimated sequentially in time, using a specification method through this RM.
2. The same approach is applied to a 3D diffusive experimental set up composed of a thick stainless steel tube subjected to five thermal loads: four heat sources and a flux boundary condition. The reduction methodology allows the identification of an experimental RM. From temperature measurements, the evolutions of the five strengths are simultaneously identified using RM and a sequential method and compared to the electrical measurements.
3. A 2D numerical example of forced convection in a parallel-plate duct is treated with a RM : 2 fluxes are identified from the knowledge of temperature data in the fluid for different positions. One advantage is that the RM order does not depend on the position of the sensors in the flow direction.
4. A 3D nonlinear heat conduction model where the conductivity was strongly temperature dependant has been reduced. RM has then been used to identify a time-varying heat flux density.
5. Finally a first approach of a 2D steady state natural convection problem is given. RM identification is made with computed data at several Rayleigh numbers [$1.5\ 10^7$ to $1.5\ 10^8$]. A comparison is made between temperature and velocity fields obtained with a DM and the RM with a very large time-saving.

[1] Videcoq E., Petit D., Model Reduction for the resolution of multidimensional inverse heat conduction problems, *International Journal of Heat and Mass Transfer*, Vol.44(10): 1899-1911, 2001.
[2] M. Girault , D. Petit , E. Videcoq. The use of model reduction and function decomposition for identifying boundary conditions of a linear thermal system. Inverse Problems and Engineering, vol.11,N°,oct.2003, pp425-455