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Laplace transform, regularized deconvolution and virtual thermal sensors

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In many cases, heat or mass transfer in a physical system can be modeled by a linear system of partial differential equations (PDE) whose coefficients do not vary with time. This is true for heat transfer in a solid, if temperature variations stay moderate, or for thermal or mass convection in a fluid, if the fluid velocity field remains stationary. If the transient excitation (heat or mass source) is unique, a Laplace transformation of the previous equations shows that the response (temperature, concentration, flux) at any point of the material system is a convolution product between this excitation and a corresponding impulse response.

Under the previous assumptions, finding this impulse response provides a reduced model which is as good as the numerical or analytical solution of the detailed PDE model. Here we show that experimental “identification” (or calibration) of this impulse response in a first step allows the use of temperature measurements, for recovering temperatures or heat fluxes at points where no sensor is present in a second “estimation” step: this corresponds to the use of a "virtual sensor". Both steps requires a deconvolution procedure, which is an ill-posed inverse problem caused by the presence of noise in the experimental signals, and a regularization is compulsory.

Applications of this two-step procedure to the characterization of heat exchangers is presented in the talk.