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In many engineering applications, the thermal state is a major influencing factor of the actual state of a structure. This is for instance the case in large civil engineering structures where temperature variations induce modifications of the mechanical vibrational properties. In building construction, the thermal state is the main variable characterizing both the interior comfort provided to the occupants and the overall energy performance of the building. In such cases, monitoring the thermal state in real time becomes a valuable information for the control of the desired characteristics.

Sensing technology can only provide partial information on the thermal state. The most commonly used sensors deliver pointwise, curvilinear or surface measurements (*e.g.* thermocouples, Raman-type fiber optics or infrared thermography devices). Some parts of the structure may be inaccessible to measurements. Some devices, like infrared thermography sensors, are not suited for permanent monitoring. Accurate real-time temperature can however be obtained through a suitable data assimilation procedure that consists in combining partial information collected in the field with a numerical model.

The issue here is the reconstruction of a temperature field using pointwise measurements. We consider a structure occupying a domain $\Omega$, and we assume that $m$ sensors placed at locations $x_k$, $(k = 1..m)$, inside the structure permanently deliver transient measurements $\theta_k^d(t)$ over time. Based on a recording of these measurements over a time interval $[0, T]$, the aim is to determine with the best possible accuracy the current temperature field $\theta(x, T)$. The computational procedure must be fast enough so that the assumption of a constant temperature during the decision-making process can hold.

The proposed method relies upon optimal control theory applied to determine both the initial and boundary conditions. The unknowns are determined in a way that they minimize a quadratic cost function in a least-squares sense, with Tikhonov regularization to deal with the ill-posedness of the inverse problem. The adjoint method is used to determine the gradient of the cost function. We show how the introduction of extra regularity assumptions, which amounts to considering a first order Tikhonov regularization functional, cures the usual lack of convergence at final time, while the resulting framework proves systematic, rational and easy to apply.

By exploiting duality, the problem can be set in the space of observations. This space is essentially one-dimensional and its discretization leads to much fewer unknowns. Furthermore, the minimization of the dual functional consists in the inversion of a square grammian matrix which is independent of data and can be constructed once for all. This shifts most of the computational effort in an off-line pre-computation stage, thus enabling for fast real-time on-line computations. The method can be applied to multidimensional situations at the price of an *ad hoc* numerical apparatus coping with the lack of definition of pointwise quantities of interest.

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