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Preconditioning for a Model of Cell Adhesion

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Abstract: We consider an application from biology where a mathematical model is developed to describe a cell adhesion process.
In biology, cell adhesion describes the binding between two cells or between a cell and the extracellular matrix through certain proteins, called cell-adhesion molecules. Cell adhesion is responsible for tissue formation, tissue stability and - in case of loss of the adhesion - also for a cell breakdown.
Armstrong et al. published in 2006 a continuous model that describes cell adhesion in contrast to the discrete nature of the previously published models. For example, in the one-dimensional case, the force at location x that describes the adhesive forces is built from local forces at $x+y$, where y ranges over an interval $[-R, R]$ and is of the following form, a nonlocal operator,

$$K(u)(x) = \int_{-R}^{R} g(u(x+y)\omega(y))dy.$$

Adding diffusion this leads to an equation of the type

$$u_t = Du_{xx} - (uK(u))_x.$$

This is the prototype for more complex model including systems and more-dimensional spatial variables. Similar models have been investigated in modeling option prices where the underlying stochastic process is of jump diffusion type. Optimal control comes into play when parameters have to be estimated by fitting the output data.
It is obvious that for a fast numerical solution preconditioning is essential. Often the point of view is taken that the diffusive part needs preconditioning whereas the integral part is of smoothing type, even a compact operator, and hence no preconditioning is necessary. However, we show in this talk that this is misleading because the smoothing property of K depends strongly on the shape of the distribution function ω. We underscore this observation by numerical experiments.
This is joint work with Lukas Zimmer, Universität Trier, Germany