Analysis of the system Jacobian of a reservoir simulation model

Supervisor: Johan Romate (Shell/TUD)

Problem background
Central to petroleum reservoir simulation is the numerical solution of equations describing the transport of mass, momentum and energy of fluids moving through a porous medium. These fluids consist of many different chemical components, but on a macroscopic level behave as continua in which a limited number of phases can be distinguished, each with its own physical properties and flow behaviour. Typical phases present are the gas phase (a vapour phase consisting mainly of light hydrocarbon components such as methane, and components like carbon dioxide), the oil phase (a liquid phase consisting mainly of the heavier hydrocarbon components), and the aqueous phase (a liquid phase consisting mainly of water). The collected equations describing the porous media flow then is a *multiphase* flow model. There are various multiphase flow models used for reservoir simulation, typically depending on the purpose and requirements of the simulation. Due to the physical complexity of flow through a porous medium, we cannot always incorporate all aspects of the flow in all detail in the macroscopic continuum models and simplifying assumptions and empirical correlations are needed to close the models for practical purposes. Unfortunately, we know that in some of the models problems can occur in the solution process, which can manifest themselves through problems with solver convergence or the total breakdown of the solution process. In [1], for instance, the authors show that their three-phase model for incompressible porous media flow can become ill-posed due to an operator becoming locally elliptic, where it is otherwise hyperbolic.

Assignment
In Shell there are various reservoir simulation models in use, and in certain situations models can fail to give a solution of an apparently well-defined problem. There are indications that at least some of such failures can be ascribed to a form of ill-posedness of the model being used. In this assignment one or more of these cases will be investigated for such a relation between solver failure and model characteristics. In particular, it will be interesting to see if and what the system Jacobian being used in the simulation can tell us about the possible causes. Hence, in this assignment the focus will be first on finding indicators for possible problems, and later (if there is time) on the analysis and prevention of such problems. The assignment consists of the following parts:

1. Literature study.
2. Inventory of problem cases within a given model class.
3. Analysis of the associated model structures and the system Jacobians.
4. Developing a practical indicator of model ill-posedness.
5. Implementing and testing the indicator.
6. Writing the thesis.

Literature
[1] J. B. Bell; J. A. Trangenstein; G. R. Shubin: Conservation laws of mixed type describing three-phase flow in porous media.
SIAM J. Appl. Math., vol.46, 1986, pp. 1000–1017.