T. Richter: Efficient Simulation of Temporal Multiscale Problems

The coupling of different temporal scales is common in many application problems. A classical example is the weathering of mechanical structures like bridges. This process takes decades, it is however affected by short term influences such as traffic, wind or stretching by daily and yearly temperature alteration. The problem is two-way coupled as material change could cause a shift of resonance regimes with a drastic influence on the fast scale. Another example is the growth of atherosclerotic plaques in blood vessels, a bio/chemical mechanism that causes material transformation and growth in the vessel walls in the time-span of months but that is strongly affected by the mechanical forces arising from the pulsating blood flow in a fluid-solid interaction system. Narrowing of the blood vessel will naturally also affect the fast scale by changing the overall flow pattern.

These slow-scale / fast-scale problems have in common that they are two-way coupled processes and that we are usually interested in the slowly evolving scale only. A resolved simulation of all scales is not feasible. A year comprises 30 million heart cycles, a corresponding resolved fluid-solid simulation is out of bounds.

Based on the replacement of the fast-scale problem by equations with periodic solutions we describe and analyze temporal multiscale schemes for the efficient simulation of such problems. An important ingredient is the quick approximation of these periodic problems for which we present some acceleration schemes. Test cases inspired by the atherosclerotic plaque growth problem demonstrate the possible benefits by such multiscale methods.