Numerical challenges in the dynamical simulation of mechanical and mechatronic systems

M. Arnold[1]

[1]Martin Luther University Halle-Wittenberg, Germany, martin.arnold@mathematik.uni-halle.de

Nonlinear dynamical simulation provides the basis for controller synthesis, optimization and optimal control of mechanical and mechatronic systems in vehicle system dynamics, robotics, biomechanics and other fields of application. In history, it has benefited much from the progress in ODE and DAE time integration from the 1970's to the 1990's.
The traditional approach in this field are BDF or implicit Runge–Kutta methods with step size and order control that are combined with index reduction techniques to handle the constraints in the DAE case. In each time step, the corrector equations are solved by some sort of simplified Newton method with topological solvers for the arising systems of linear equations [1].
In industrial multibody system simulation tools these very efficient numerical solvers are today also used beyond their classical range of applicability to simulate very complex engineering systems that include, e.g.,

- distributed physical phenomena being described by (coupled) PDEs,
- frequent discontinuities caused by impacts an non-smooth friction elements,
- multiple time scales and
- nonlinear configuration spaces to allow the representation of large rotations without singularities.

In this framework, classical higher order ODE and DAE time integration methods become less and less important and are complemented by

- modular time integration methods for coupled and multiscale problems,
- iterative solvers for the systems of linear equations in the corrector iteration,
- linear and non-linear model order reduction techniques for certain model components,
- time stepping methods for discontinuous systems and
- Lie group methods for nonlinear configuration spaces.

All these novel approaches proved to be very favourable in a number of reference applications but it still remains challenging to achieve in daily use the very high level of reliability and robustness that is known from classical ODE and DAE time integration methods.
In the talk, we will discuss some of these open problems and show that lower order time integration methods from structural dynamics (Newmark integrators) provide in this context an interesting alternative to BDF and higher order (implicit) Runge–Kutta methods.

References

[1] M. Arnold, B. Burgermeister, C. Führer, G. Hippmann, and G. Rill. Numerical methods in vehicle system dynamics: State of the art and current developments. *Vehicle System Dynamics*, 49:1159–1207, 2011.