

IFDIFF – A Matlab Toolkit for ODEs with State-Dependent Switches

In this talk, we present a methodology to automate detection and handling of implicit (state-dependent) switching in ODEs, which are given as computer code. Naïve implementations using IF-THEN-ELSE branching give unreliable simulation results without warning, as switching events are undetectable by standard integrators. The widespread belief that this can be countered using more stringent integration tolerances is wrong: We give a simple example where the integrator's error estimation always delivers zero.

We review the classical switching point ansatz of monitoring switch-defining functions for zero-crossings. Correct treatment of switched systems requires elaborate formulation of these switching functions and tailored integrators, placing high mathematical demands on modelers. Even small model changes often imply considerable reformulation effort. Furthermore, n switches may generate up to 2^n possible program flows and switching functions, rendering a-priori formulations not feasible already in medium-sized models.

We present the toolkit IFDIFF for integration and sensitivity generation in parameterized implicitly switched ODEs whose right-hand side is given as Matlab code containing non-differentiable operators (max, abs, etc.) and conditionals (if). Using augmented conditional operators and on-the-fly switching function generation, accurate simulations and sensitivity information can be delivered, while minimizing required user interaction. IFDIFF programmatically handles switching events, auto-generating only required switching functions. It determines switching times up to machine precision, and ensures accurate simulation and sensitivity results. Transparently extending the Matlab integrators (ode45, ode15s, etc.), IFDIFF is applicable to existing code with state- and parameter-dependent conditionals, thus enabling fast prototyping and relieving modelers of mathematical-technical effort.

(Co-)Authors

Andreas Sommer, IWR – Heidelberg University, Germany, andreas.sommer@iwr.uni-heidelberg.de

Hans Georg Bock, IWR – Heidelberg University, Germany, bock@iwr.uni-heidelberg.de

Ekaterina Kostina, IWR – Heidelberg University, Germany, kostina@iwr.uni-heidelberg.de