Population and ODE-based models using Stan and Torsten

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Length: 1 day

Description:
This class focuses on fitting models in pharmacometrics. We consider the following challenges when building such models: (i) the data generating process involves solutions to ODE systems, (ii) these ODEs are embedded in a complicated event schedule, and (iii) the data comes from various sources, for instance various patients and studies, and the resulting models are hierarchical. Note that these properties are not specific to pharmacometrics, and arise in other fields such as epidemiology, geology, and econometrics. To accommodate a broad audience, we will keep the core concepts general, and review basic notions of pharmacometrics, so that participants from all fields can do the exercises.

The course covers elementary techniques to solve ODEs in Stan, the efficient parametrization of hierarchical models, and within-chain parallelization. We also introduce *Torsten*, an extension of Stan for pharmacometrics, which allows us to seamlessly combine the above methods.

Prerequesites:
Participants should be familiar with Bayesian statistics and basic Stan. The requisite material is covered in the introductory tutorial and the tutorial on hierarchical modeling at Stan Con 2019, which participants can attend before coming to this workshop.

Outline:

1. Course information
2. Introduction
    - Modeling framework: build, fit, and criticize

- Review: diagnosing inference
- Review: criticizing the model

3. Models in pharmacometrics

    - Compartment models
    - The event schedule
    - Torsten: a library of Stan functions for pharmacometrics
    - *Exercise 1: build, fit, and diagnose a two compartment model*

4. Ordinary differential equations in Stan and Torsten

    - Arsenal of tools to solve ODEs
    - Matrix exponential solution for linear ODEs
    - Numerical integrators for nonlinear ODEs
    - *Exercise 2: write, fit, and diagnose a two compartment model with the ODE integrator or Matrix exponential solver*

5. Numerical ODE integrators

    - example: kinetics of autocatalytic reaction
    - *Exercise 3: specify ODE system for autocatalytic reaction model*
    - Numerical integrators: rk45, bdf, and Adams-Moulton
    - *Exercise 4: build and fit the full autocatalytic reaction model*

6. Population models

    - Review of hierarchical models
    - *Exercise 5: write, fit, and diagnose a population two compartment model*
    - Divergent transitions and where they come from
    - *Exercise 6: re-parametrize the population two compartment model*

7. ODE group integrators

    - group integrators in Torsten

- *Exercise 6: parallelize the autocatalytic reaction model using the group integrator*

8. PMX population solvers
    - Time to event model
    - *Exercise 7: specify the ODE system for time to event model.*
    - *Exercise 8: use the group solver to parallel solve the ODE*
9. Open discussion and concluding remarks.