Mixed-Effects Modeling of Dynamic Systems for Longitudinal Data with Applications to HIV/AIDS

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Differential equation models are widely used to describe dynamic systems in many scientific fields such as engineering, physics, econometrics, and biomedical sciences. A critical question for differential equation modeling in these scientific fields is the so called “inverse problem”, i.e., how to determine or estimate the unknown parameters and perform statistical inference for the differential equation models based on experimental data. Although this is an important and well-defined statistical problem, very few statisticians pay attention to this problem due to unfamiliar with the scientific background. In this talk, I will present several new methods to address the following questions for differential equation models: 1) identifiability of parameters in nonlinear ordinary differential equations; 2) statistical methods for parameter estimation: the nonlinear least squares method, Bayesian method, and two-stage methods; and 3) extension to longitudinal data. Application examples from HIV viral dynamic studies will be used to illustrate the proposed methods. Some new challenges in this research direction will be discussed.