Generalized Linear Mixed Models
PhD School in Statistical Sciences, University of Padova

Instructors

Leonardo Egidi, DEAMS, University of Trieste
(`legidi@units.it`)

Ruggero Bellio, Department of Economics and Statistics, University of Udine
(`ruggero.bellio@uniud.it`).

Course description

This course is designed to briefly review the Generalized Linear Models (GLMs) and introduce mixed-effects (hierarchical) models with real-data applications. During the course, relevant theoretical results will be reviewed and practical issues arising in modeling complex data (i.e., correlated or clustered data) will be considered. The students will learn how to (i) write a multilevel model, (ii) implement the model using likelihood and Bayesian methods (the latter with the Stan software + Hamiltonian Monte Carlo sampling within the R environment), (iii) obtain inferential conclusions, (iv) check the model, (v) make predictions.

Program

1. A quick introduction to Generalized Linear Models (GLMs): structure and inference
    - Poisson regression
    - Logistic regression
    - Overdispersion, offset term, residual analysis
2. Extending GLMs: First instances of models for hierarchical data
3. Likelihood Methods for Mixed Models
    - Linear Mixed Models (LMMs)
    - Generalized Linear Mixed Models (GLMMs)
    - Practical session with R
4. Bayesian hierarchical/multilevel models
    - Partial pooling
    - Varying intercept models + varying intercept and slope models
    - Prior distributions for hierarchical models
    - Examples: Cockroach data; Eight school data; Covid-19 real-data

5. Hamiltonian Monte Carlo sampling
    - Sketch of Markov-Chain Monte Carlo methods
    - Posterior geometry and divergences
    - Introduction to Stan
6. Model checking and model comparison
    - Posterior predictive checking
    - Posterior graphical analysis
    - Leave-one-out cross-validation
7. Predictions
    - Prediction of new observations in existing groups
    - Prediction of new observations in new groups

Recommended texts

- McCullagh, P. & Nelder, J. A. (1989). *Generalized linear models*, 2nd edition, Chapman & Hall/CRC.
- Pinheiro, J. & Bates, D. (2000). *Mixed-effects models in S and S-PLUS*, Springer.
- Gelman, A. & Hill, J. (2006) *Data analysis using regression and multilevel/hierarchical models*, Cambridge University Press.
- Gelman, A., Carlin, J. B., Stern, H. S. & Rubin, D. B. (2013). *Bayesian Data Analysis*, 3rd ed., Chapman & Hall/CRC, Boca Raton.
- Gelman, A., Hill, J. & Vehtari, A. (2020). *Regression and Other Stories*, Cambridge University Press.

Final Exam

The final exam consists of an oral presentation of a practical project given by groups of 2-3 students. The exam covers both theoretical and practical issues. The groups must submit their projects' presentations the day before the exam takes place.